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STUDIO**
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STANDARD 2-IN-1

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DOES WINDOWS 11 TPM MESS

UP HOW THE INTERNET WORKS

LEARN MORE WITH WINDOWS'
NEW FILE SYSTEM

PERGUIDE:

**PIRMEBOOK
FOR WINDOWS?**

TOP CHOICES TESTED
AND COMPARED



APPLE MAC STUDIO + STUDIO DISPLAY

THE ULTIMATE PRODUCTIVITY PC?

APC LABS VERDICT



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- SPI Firewall, 802.11ac Wave 2 Wi-Fi
- 16 x VLANs, 32 x VPN tunnels (including 16 x SSL-VPN tunnels)
- Support Central VPN, AP, Switch Management

Vigor2927 LTE Series

Cat.6 4G LTE and Ethernet Security Firewall Routers



- Cat.6 4G LTE Multi-WAN routers with 2 x SIM card slots, 300Mbps download, and 50Mbps upload speeds
- 1 x fixed GbE WAN port, 1 x configurable GbE WAN/LAN port, 1 x USB port for 3G/4G LTE modem, and 2 x Wi-Fi WANS (Lac model)
- SPI Firewall, 802.11ac Wave 2 Wi-Fi
- 16 x VLANs, 50 x VPN tunnels (including 16 x SSL-VPN tunnels)
- Support Central VPN, AP, Switch Management

Vigor2866 LTE Series

Cat.6 4G LTE and VDSL2 35b/G.fast/Ethernet Security Firewall Routers



- Cat.6 4G LTE Multi-WAN routers with 2 x SIM card slots, 300Mbps download, and 50Mbps upload speeds
- VDSL2 35b/G.fast/ADSL2+ WAN port, 1 x configurable GbE WAN/LAN port, 1 x USB port for 3G/4G LTE modem, and 2 x Wi-Fi WANS (Lac model)
- SPI Firewall, 802.11ac Wave 2 Wi-Fi
- 16 x VLANs, 32 x VPN tunnels (including 16 x SSL-VPN tunnels)
- Support Central VPN, AP, Switch Management

Vigor2620Ln

4G LTE and VDSL2 35b/Ethernet Security Firewall Router



- Cat.4 4G LTE router with dual SIM card slots (SIM slot 2 for failover)
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- SPI Firewall
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- Central AP Management



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INTRO

EDITORIAL

WHAT'S INSIDE APC



"Unlike the boring old internet that hardly anyone looks at anymore, magazine pages are finite, so to fit in the good new things some old things must go."

EDITORIAL

Housekeeping

The keeping of the house



BEN MANSILL
Wants an Apple Mac Studio to make Indesign page scrolling and zooming smoother.

Hello everyone. I hope your 2022 so far has been a delightfully breezy and effortless cruise through a problemless panorama of success and joy.

Last month, I used up all the space here telling you about the new regular sections we've added to APC. Very exciting stuff it is, and I hope you've taken a shine to our new bits. If you missed the last episode of *APC in Action*, we added Futures (page 22) to look ahead, Retro (page 110) to look back, A-List (page 26) to tell you what's hotter than hot, and Jon Honeyball's One More Thing column (page 18), where Jon will often complain that things were better in the old days.

Unlike the boring old internet that hardly anyone looks at anymore, magazine pages are finite, so to fit in the good new things some old things must go. So now, a quick word on what we taketh away.

You don't need APC to tell you the latest game news. So we shan't any more. By the time you've read our pages you already know that Microsoft's bought Activision, or that Randy Pitchford has a fresh new sound bite expressing his mountainous enthusiasm for his new project. We'll let the internet handle that for you. Good job, internet.

Nor will we be paying much attention anymore to IOS apps and guides. We're APC, not *Handy Dandy iPhone Top Tips*. So none of that anymore. But we will still be covering Android because thanks to Windows 11 (thanks, Windows 11), Android apps and your PC are now best friends.

We're upping the number of features we run, seeing as we have many of the world's finest journo's on hand to tell great stories about tech. It's more work and research for the team, but it's well worth it. We see a big part of our role as giving you insight you would struggle to find elsewhere (looking at you, internet). And we'll be focussing on really interesting topics, too, so it's all just a good read.

Those long 12-page how-to-build-a-PC tutorials? Fewer of them, I think. Certainly not in every issue, at least. I do like those, and the team love putting them together, but you don't need to be taught how to build a PC every single month. We have our long-running Blueprints section (it's staying!) that 'virtually' assembles three different PCs each issue, and the mission there is to give you a monthly updated look at the best choices in gear, even in this over-priced market.

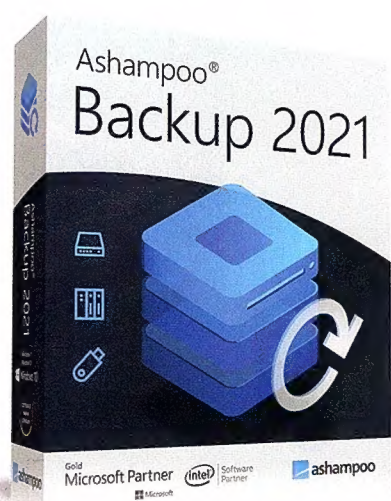
So, we think we have you covered, and hope very much that these small finesses make APC an even more enjoyable read for you each month.



The *APC Badge of Newness* tells you that you really can believe your eyes, and this wonderful new content is here, and here to stay.

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Your free full-version apps as a thanks for reading APC. These exclusive downloads will only be available for a limited time, from 18/04/22 to 05/06/22.

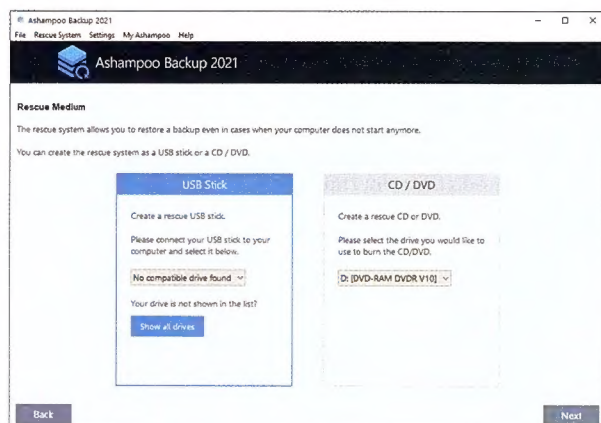


ASHAMPOO BACKUP 2021

Backup software to easily back up and restore entire partitions.

Ashampoo Backup 2021 backs up and restores entire disk partitions, including bootable Windows installations, in just a few clicks. Incremental auto-updates ensure backup files are always up-to-date and prevent data loss. The user interface was designed with simplicity in mind and is intuitively usable by anyone. Backups are always restorable, even in the event of highly corrupt or ransomware-infested systems, thanks to a built-in rescue feature that requires no technical knowledge. This backup software is self-explanatory and streamlined to cover the most essential features so there is no learning curve. Backups are automatically and incrementally updated without the need for manual intervention.

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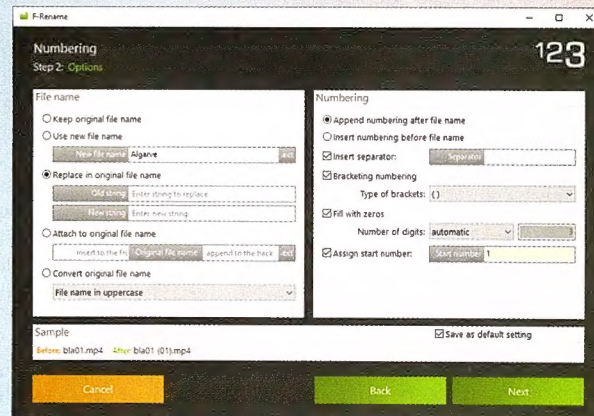
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The individual renaming function offers the highest possible flexibility. Not only does it allow you to use many tags, but it also helps to convert, shorten, and partially or completely replace existing file names. The preview and log features ensure that you never lose track of your valuable data.

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APPLE MAC STUDIO + STUDIO DISPLAY

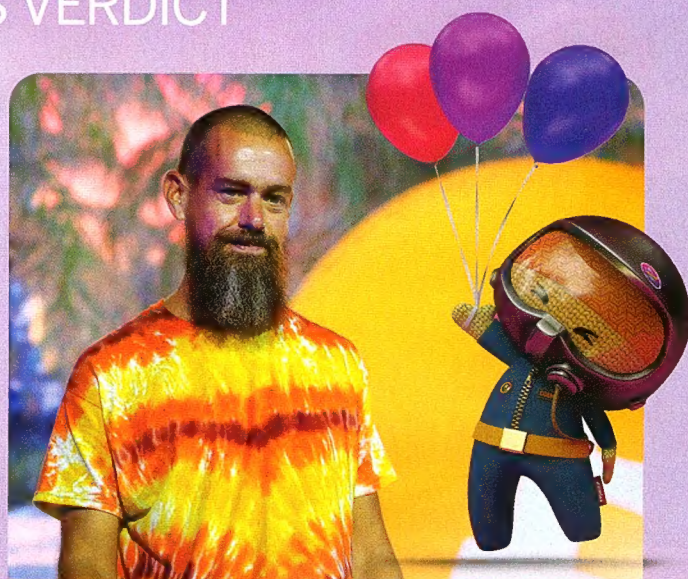
THE ULTIMATE PRODUCTIVITY PC?

APCLABS VERDICT



MOORE, MOORE, MOORE

It's not dead. It isn't slowing down. It's not even sick. Give it up for Moore's Law, the computing paradigm that's still very much alive and kicking **Page 60**



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“Championing technology doesn’t mean we’re unrelenting yes-men and -women, however, and APC aims to be as objective as possible in all our coverage.”

HOW WE DO IT

Inside APC

Find out all about APC’s editorial policies, test practices, how to read the benchmark results, and more.

APC is Australia’s oldest consumer technology magazine – having been consistently in print for forty years, since our first issue way back in May 1980 – and we take that heritage and responsibility very seriously. While our focus is obviously on the personal computer the very definition of the PC has changed and shifted markedly since the early 1980s. As such, we touch on many other areas of tech, too, from smartphones and apps to peripherals, accessories, and beyond. We have two goals: to find the best modern tech and to help you make the most of it.

We’re also an open church in terms of platforms. We know most people aren’t wed to a single brand’s products and use a variety of devices. And, like you, APC’s journalists want to know what’s good in tech – no matter what platform it resides on.

Independent reviews

Championing technology doesn’t mean we’re unrelenting yes-men and -women, however, and APC aims to be as objective as possible in all our coverage. That means identifying the best products from multiple perspectives – the best performance, best value and best features and, ideally, the products that offer the best mix of these three attributes.

As a matter of policy, reviews published in APC are not shared with product-makers prior to print. We will contact vendors under certain conditions; for example, if we have a problem testing a product that seems to indicate it may be faulty, or to invite a vendor to clarify how a particular feature works. If an APC reviewer has any potential conflicts of interest involving a brand, the review will always be assigned to another writer.

Labs testing

APC strives to conduct the most rigorous, objective scientific tests and benchmarks we can so as to make our reviews as unbiased as possible. We use a variety of tools and programs for this, including many freely available benchmark suites for assessing media encoding, general system performance including storage read and write speeds, gaming and battery life.

In most cases, for the benchmark results published in APC, you can assume that higher is better. There are certain tests that deviate from this rule where the opposite is true; in those cases, we’ve flagged the results with a note explaining as such.

We use both tables and graphs for displaying results; the latter offers better ease-of-readability, but tables are more compact, so we use these in most cases where thoroughness is preferred. ■

APC TESTBED

The current APC testbed used in the Labs for benchmarking all components. This testbed is updated as new and relevant technology comes on stream.

CPU	AMD Ryzen 7 5800X
Motherboard	Asus ROG Crosshair VIII Dark Hero
GPU	Zotac RTX 3080 Ti AMP Extreme Holo
Memory	Crucial Ballistix Sport DDR4-3600 2x16GB
Primary SSD	Adata S70 2TB NVMe
Secondary SSD	Samsung 980 Pro 500GB NVMe
Cooling	Nzxt X73 360mm AIO
Case	Thermaltake Core P8
Power Supply	Corsair AX1000

APC AWARDS



APC EDITOR'S CHOICE
When a reviewed product scores 4.5 out of 5 or higher, it carries the Hot Award. These are products that exceed expectations and deliver a quality experience up there with the very best.



APC HIGHLY RECOMMENDED
You will see this award if a reviewed product has scored four out of five stars. It means most people can expect satisfying performance from the product, and that we would use it ourselves.



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TESTED

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Earbuds EVOLVED

Innovative buds offering smarter sound



DITCH THE SWITCH!

Next-gen portable consoles for gaming on the go



RATED

SOUNDBARS & SURROUND SPEAKERS

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REVIEWED

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RETRO COMPUTING MUSEUM IN UKRAINE DESTROYED BY RUSSIAN BOMB

Over 500 tech exhibits obliterated.

A privately owned collection of more than 500 pieces of retro computer and technology history has been destroyed by a Russian bomb in the city of Mariupol. The war in Ukraine is a tragedy on so many levels, but while it in no way matches up to the senseless taking of lives by the invading Russian forces, the destruction of the Mariupol Computer Museum is still saddening.

The destruction was highlighted by Mark Howlett on Twitter, and confirmed by the Ukrainian Software and Computer Museum account, which operates museums in Kharkiv and Kyiv. The owner of the Mariupol collection, Dmitry Cherepanov, is reportedly safe, though his collection of computers, consoles, and assorted tech from fifty years of computing has been wiped out.



HACKERS TARGET INTERNET-CONNECTED UPS DEVICES

Hackers can fry PCs, literally.

The Cybersecurity and Infrastructure Security Agency (CISA) on Tuesday warned US organisations that hackers are now targeting Internet-connected uninterruptible power supply (UPS) devices. Such attacks can literally fry PCs, or at least their power supplies, but the more dangerous outcome is that they can cause fires in datacentres, homes, and offices.

In a bid to avoid attacks on mission critical machines, CISA recommends organisations ensure that their UPS is not reachable via the internet. Since this is sometimes impossible to do, CISA also recommends using strong passwords or passphrases, enabling multifactor authentication where available, implementing login timeout/lockout policies, and hiding any UPS devices behind virtual private networks.

A-Series Mobile Graphics					
	XeSS		Xe Media Engines		PCIe Express 4.0
	XII ULTIMATE		XMX AI Acceleration		
	Intel ARC 3		Intel ARC 5		Intel ARC 7
	A350M	A370M	A550M	A730M	A770M
Xe-cores	6	8	16	24	32
Ray Tracing Units	6	8	16	24	32
Graphics Clock (MHz)	1150	1550	900	1100	1650
Memory (GDDR6)	4 GB	4 GB	8 GB	12 GB	16 GB
Memory Bus Width	64-bit	64-bit	128-bit	192-bit	256-bit
Graphics Power	25 - 35W	35 - 50W	60 - 80W	80 - 120W	120 - 150W
Available Starting Now			Available in Early Summer		

GPU NEWS

Intel reveals full details for its Arc A-Series

Desktop GPUs still coming at a later date.

Intel Arc Alchemist officially enters the GPU fray, turning this two-pony race into a three-way battle for supremacy. The Arc A-Series mobile GPU lineup will see the first laptops sporting the new GPUs slated to arrive in April. But desktop users need not worry: Arc graphics cards for desktops are still coming, just not first.

Similar to its CPU stack, Intel's Arc Alchemist will have multiple tiers of performance: Arc 3, Arc 5, and Arc 7. The various models will be based off two chip designs, one with up to 96 Xe Vector Engines (XVE) and the other with up to 512 XVE. Note that XVE is the new name for what was formerly called an EU (Execution Unit), though the new XVE makes plenty of changes and certainly warrants a change in name.

The smaller chip is called ACM-G11, and it will launch first, with laptops expected to arrive shortly using the new Arc 3 branded GPUs. ACM-G10 uses a significantly larger chip and Intel expects laptops using the Arc 5 and Arc 7 GPUs to arrive by early winter.

In most respects, ACM-G10 has four times the hardware of ACM-G11: 4X the Xe-cores, ray tracing units, and L2

cache. The memory subsystem however is 2.67x as wide, with a maximum 256-bit bus compared to a maximum 96-bit bus on the smaller chip, and the PCIe slot interface is twice as wide at x16 vs. x8. The media and display capabilities meanwhile are equivalent between the two GPUs, so all Arc graphics solutions will have the same dual Xe Media Engines (MFX) and four display engines.

Intel is particularly pleased with Arc's media capabilities, which contain industry-first hardware-accelerated AV1 video encoding support. The two engines support up to 8K60 10-bit HDR encoding support, with 8K60 12-bit HDR decoding. Besides AV1, Arc also supports the VP9, AVC (H.264), and HEVC (H.265) video codecs. AV1 was created by the Alliance for Open Media, with Intel, Amazon, Apple, Google, Netflix, Nvidia, Samsung, Facebook, Microsoft, and others signing on. AV1 can provide improved video quality within the same bandwidth, or the same quality as H.264 with about half the bandwidth, or 20 percent less bandwidth than H.265.

The Arc A-Series mobile GPU lineup will see the first laptops sporting the new GPUs slated to arrive in April. But desktop users need not worry: Arc graphics cards for desktops are still coming, just not first.

Arm to layoff hundreds after failed Nvidia buyout

Potentially up to 1,000 jobs.

According to *The Telegraph*, Arm chief executive Rene Haas advised staff that hundreds of employees will be let go after the acquisition fell through. Between 12 and 15 percent of the company's employees are expected to be affected, mostly in the US and the UK. Given Arm's workforce is over 6,500 people strong, that could be nearly one thousand jobs on the chopping block across the company.

"This is going to be a tough time for everyone, so I want to be clear on why we are doing this," Haas said in an email according to *The Telegraph*. "We need to be more disciplined about our costs and where we're investing. To stay competitive, we need to remove

arm

duplication of work now that we are one Arm; stop work that is no longer critical to our future success; and think about how we get work done."

This sounds like Arm is going to become an even more focussed company than it already was. It could be that Arm's semiconductor technology may start to go in a new direction after the shuffle is complete, but company layoffs aren't usually a good sign.

"To stay competitive, we need to remove duplication of work now that we are one Arm; stop work that is no longer critical to our future success; and think about how we get work done."



PLAYSTATION 5 CHIPS MIGHT BE SHOWING UP IN CRYPTO MINING RIGS

Ever wonder what happens to a defective PS5?

AMD might be taking the APUs (the combined CPU and GPU chip) from broken PlayStation 5 consoles and repurposing them for expensive crypto mining rigs.

The Asrock BC-250 mining rig, which features 12 AMD BC-250 mining cards, might have the APUs from defective Sony PlayStation 5 consoles, according to leaker Komachi. There's no CPU listed on the

product page, which means that one of the PS5 APUs' CPUs is most likely handling non-mining related tasks. The rig uses 16GB GDDR6 RAM, which is coincidentally how the PlayStation 5 is set up.

With something like 10 million PlayStation 5s out there globally, it makes sense that a percentage of them would be bricked but still have a serviceable APU.



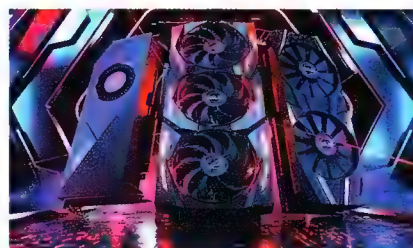
FCC LISTS KASPERSKY AS A NATIONAL SECURITY THREAT

The first Russian company on the FCC's list of security risks.

The cybersecurity company Kaspersky Labs has become the first Russian company to make the US Federal Communications Commission (FCC) list of entities that present an "unacceptable risk to US national security."

What this means in practice is that US businesses are forbidden from using federal subsidies to purchase equipment or services, which is obviously some distance from an outright ban or the trade embargo that crippled Huawei's ability to use Android back in 2019.

Nonetheless, Kaspersky is understandably affronted by the decision, and put out a press release claiming that the move "is a response to the geopolitical climate" rather than being based on any concerns about the quality or otherwise of the company's products.



ASUS TO CUT GPU PRICES BY UP TO 25 PERCENT

All SKUs will reportedly be slashed.

Asus has confirmed that it is slashing graphics card prices by up to 25 percent. In an email statement an Asus representative added that price reductions will be applied to its entry-level, mid-range and high-performance models. The company cited cuts to the tariffs on US imports from China as a major reason behind the MSRP reductions.

"As a result of the latest tariff lift on Chinese imports from the Office of the United States Trade Representative, Gamers and PC enthusiasts will see lower prices on Asus GeForce RTX 30-series graphic cards starting on April 1st, 2022," an Asus rep told us.

The MSRP cut of 25 percent isn't being applied across the board. As Asus puts it, "Consumers should expect prices to decline up to 25 percent on different models throughout the springtime." ■

TECH BRIEF

Nvidia unveils Big Accelerator Memory

Solid-state storage for GPUs.

Microsoft's DirectStorage application programming interface (API) promises to improve the efficiency of GPU-to-SSD data transfers for games in a Windows environment, but Nvidia and its partners have found a way to make GPUs seamlessly work with SSDs without a proprietary API. The method, called Big Accelerator Memory (BaM), promises to be useful for various compute tasks, but it will be particularly useful for emerging workloads that use large datasets. Essentially, as GPUs get closer to CPUs in terms of programmability, they also need direct access to large storage devices.

Modern graphics processing units aren't just for graphics; they're also used for various heavy-duty workloads like analytics, artificial intelligence, machine learning, and high-performance computing (HPC). To process large datasets efficiently, GPUs either need vast amounts of expensive special-

purpose memory (e.g., HBM2, GDDR6, etc.) locally, or efficient access to solid-state storage. Modern compute GPUs already carry 80GB–128GB of HBM2E memory, and next-generation compute GPUs will expand local memory capacity. But dataset sizes are also increasing rapidly, so optimising interoperability between GPUs and storage is important.

There are several key reasons why interoperability between GPUs and SSDs has to be improved. First, NVMe calls and data transfers put a lot of load on the CPU, which is inefficient from an overall performance and efficiency point of view. Second, CPU-GPU synchronisation overhead and/or I/O traffic amplification significantly limits the effective storage bandwidth required by applications with huge datasets.

BaM essentially enables Nvidia GPUs to fetch data directly from system memory and storage without using the CPU, which makes GPUs more self-sufficient

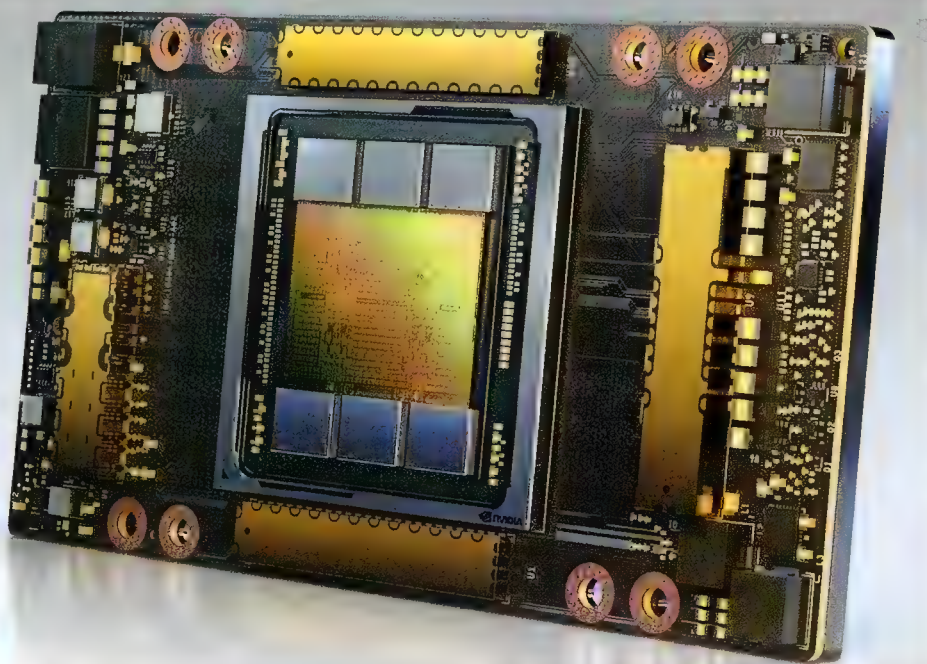
than they are today. Compute GPUs continue to use local memory as software-managed cache, but will move data using a PCIe interface, RDMA, and a custom Linux kernel driver that enables SSDs to read and write GPU memory directly when needed. Commands for the SSDs are queued up by the GPU threads if the required data is not available locally. Meanwhile, BaM does not use virtual memory address translation and therefore does not experience serialisation events like TLB misses. Nvidia and its partners plan to open-source the driver to allow others to use their BaM concept.

"BaM mitigates the I/O traffic amplification by enabling the GPU threads to read or write small amounts of data on-demand, as determined by the compute," Nvidia's document reads. "We show that the BaM infrastructure software running on GPUs can identify and communicate the fine-grain accesses at a sufficiently high rate to fully utilise the underlying storage devices, even with consumer-grade SSDs, a BaM system can support application performance that is competitive against a much more expensive DRAM-only solution, and the reduction in I/O amplification can yield significant performance benefit."

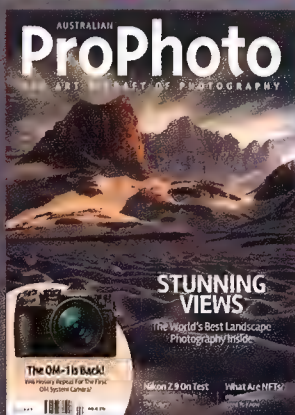
To a large degree, Nvidia's BaM is a way for GPUs to obtain a large pool of storage and use it independently from the CPU, which makes compute accelerators much more independent than they are today.

Astute readers may remember that AMD attempted to wed GPUs with solid-state storage with its Radeon Pro SSG graphics card several years ago. While bringing additional storage to a graphics card allows the hardware to optimise access to large datasets, the Radeon Pro SSG board was designed purely as a graphics solution and was not designed for complex compute workloads. Nvidia, IBM, and others are taking things a step further with BaM. **Anton Shilov ■**

BaM essentially enables Nvidia GPUs to fetch data directly from system memory and storage without using the CPU, which makes GPUs more self-sufficient than they are today.



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END USER

Flagrant Facebook scam ads won't bring the platform down, but it's another chip in its facade

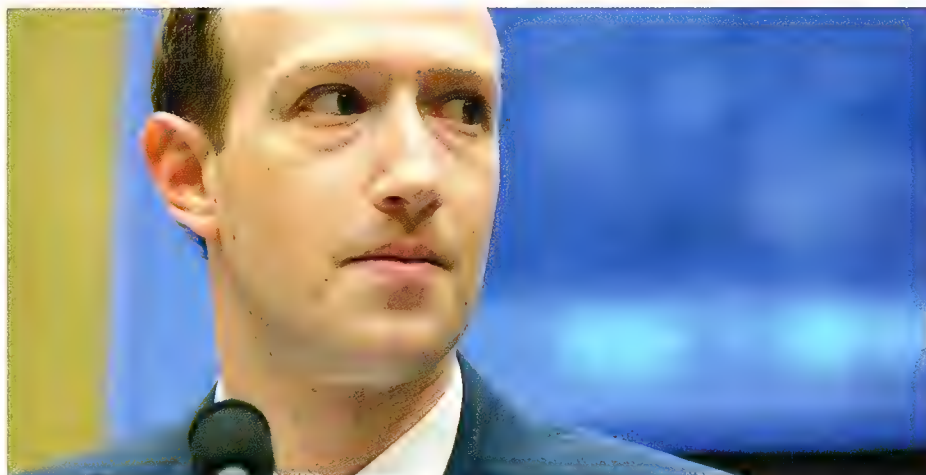
The ACCC's action against Meta is small in the wide scheme of things, but it contributes to the sense of a dying platform, writes Shaun Prescott.

Last month, the Australian Competition and Consumer Commission sued Facebook parent company Meta over scam display ads targeted at Australians. The ads used images of famous Australian businessmen, including Dick Smith and Andrew 'Twiggy' Forrest, to spruik financial scams, with one especially unlucky person losing \$650,000 to one such scam. Speaking to the ABC, ACCC chair Rod Sims said the scams have led to over \$100 million in losses to scam victims.

That's a remarkable amount of money, and if you're a scammer or an aspiring one, quite encouraging. Meta – or let's just say, Facebook – could face fines of "millions" for breaching the Australian Consumer Law, which won't exactly bring Zuckerberg's billion dollar social media empire crashing down. But the outcome of the legal action could have global implications.

Facebook's reliance on AI moderation is, once again, likely the culprit. The platform uses a blend of real human moderation and AI, and while the latter is no doubt sophisticated, it's clearly not sophisticated enough to drop the ban hammer on scam ads that, to the reasonably well-informed naked human eye, could hardly be mistaken for legitimate.

One example, screencapped by the ABC, depicts *The Project* host Waleed Aly alongside Dick Smith, presumably in discussion, with the headline "Dick Smith's Latest Investment Has Experts in Awe And Big Banks Terrified". One would need to wonder why news of this seeming consequence – albeit falsely attributed to 'ABC



News' – only gains traction via sketchy looking targeted Facebook ads.

A human moderator would undoubtedly pick that up – even if unfamiliar with those Australian talking heads – but the algorithm simply didn't. The ads are particularly brazen given their use of real world celebrity figures, and it hasn't exactly gone unnoticed: Andrew "Twiggy" Forrest sued Facebook earlier in the year for hosting scam ads that use his image.

Slamming Facebook is a popular pastime at *End User* headquarters, with countless older columns dedicated to the sport. But it's increasingly hard to imagine the platform being viable for much longer in its current manifestation. It simply cannot be effectively moderated, such is its scale. While the proliferation of scam material is worrying, likewise is the spread of misinformation and hate material, well documented elsewhere. Facebook will fight like crazy to



SHAUN PRESCOTT
Author, *PC Gamer*
editor and passionate
technology observer.
Shaun covers trending
tech topics for *APC*.

stay profitable, but Meta Platforms Inc stock dropped dramatically in early 2022, with no signs of it reaching the heights it used to reach.

The company seems terrified, too. A *Washington Post* report in March revealed that Meta has recruited a Republican consulting firm, elegantly named Targeted Victory, to basically smear competitor TikTok. In an amusing example of flagrant hypocrisy, the campaign reportedly sought to position TikTok as "a danger to American children and society." But in addition to that pursuit, Targeted Victory's campaign was also reportedly tasked with moving the public narrative surrounding privacy and antitrust away from Meta's ballpark, and into TikTok's.

As for Meta's response to the current ACCC action, its statement was typically meaningless. "We use technology to detect and block scam ads and work to get ahead of scammers' attempts to evade our detection systems," a spokesperson told *ABC News*.

"We've cooperated with the ACCC's investigation into this matter to date. We will review the recent filing by the ACCC and intend to defend the proceedings." ■

ACCC chair Rod Sims said the scams have led to over \$100 million in losses to scam victims. That's a remarkable amount of money, and if you're a scammer or an aspiring one, quite encouraging.



RANDOM ACCESS

Intel Arc: do we really need a third GPU maker?

Is Intel's new range of discrete GPUs a game changer or just a dithering filter to steal a bit of market share?

As we begin to emerge from a global silicon shortage with the second wave crypto mining boom pretty securely in the rear view, Intel has unveiled its new range of discrete GPUs designed to accompany the next generation of thin and light gaming-capable Ultrabooks. It's actually a great time for Intel to test the market since there's still a bit of pent up demand for gaming devices, and Intel's pitch of three simple tiers of better-than-integrated graphics is a sensible option for converting people quickly. The only trouble is we're not really sure there's any need for a third major graphics card maker, especially one that produces products like those recently launched by Intel.

Intel's rough plan here is to release the Arc 3 first using a six- or eight-core GPU capable of using between 25W and 50W of power, and then offer Arc 5 and Arc 7 GPUs that range up to a full 150W power draw coming later down the track. Any of these GPUs could end up blowing us away with benchmark scores, but right now all we have to go off is Intel's own reported performance on the Arc 3.

On paper the top Arc 3 GPU



JOEL BURGESS
When not reviewing PCs for *APC* and writing our funny pages, Joel likes to ponder tech and how it's used.

suggests a 30-60 percent improvement on tasks like media encoding and a similar or better improvement on games. If the devices that eventually hit shelves actually perform this well then there may be a genuine case for the Arc 3, but it'll have some tough competition. Take, for example, Nvidia's RTX 3050Ti, which can be configured with a 50W power draw. This GPU already performs at least as well as the Arc 3, and potentially much better.

From a consumer perspective, even if Intel undercuts Nvidia by selling its discrete GPUs for less, a lot of the cost in gaming-capable ultrabooks comes from vendors designing cooling or adding battery capacity to meet the power draw... which will be comparable here. So at the end of the day a device with an Arc 3 is going to cost the same as one with a 3050 or a 3050Ti. It's a hard sell to convince people away from established components when your product isn't better or cheaper.

Nvidia also has a raft of software to optimise common issues with games and while Intel has tried to address this gap by creating its own solutions, we're apprehensive

that 'fixes' like Smooth Sync, which simply blurs out the edges of any screen tearing using a dithering filter, actually improves the gaming experience at all.

Intel could do great things for the entry level gaming laptop market, but it'll only do this by increasing the performance of integrated graphics. There's an overlap at the ultrabook pricepoint where you'll get a good quality integrated GPU with your Intel CPU, but it is made redundant by a discrete GPU that consumers pay additional money for – even though it only performs marginally better. Intel won't take the AMD route and offer GPU-less laptop processors since that doesn't help it steal discrete GPU market share, so the only option for real added value to consumers is to create integrated graphics that make entry-level discrete GPUs redundant.

Short of doing this, all Intel is doing by creating equivalent GPUs is creating more noise in the GPU landscape. I don't know about you, but the thought of having another GPU that I have to translate back into Nvidia RTX equivalents just seems like a bit of a chore. ■



TWO BITS

Don't buy a top-end PSU right now

ATX 3.0 is coming to power your next gen GPU.

Intel has published the final ATX 3.0 specification, and it's the biggest change to power supply specifications in almost 20 years. Given how much modern hardware has evolved, it's a surprise it took that long. What this means is that it's advisable to hold off on buying a high-end power supply right now if you can avoid it.

Probably the biggest change is the inclusion of PCIe 5.0 graphics card support. The new 12VHPWR connector provides up to 600 watts for supporting PCIe 5.0 graphics cards. This 12-pin connector includes four additional sideband signals that improve power delivery. Note that it's not the same as the one that's found on Nvidia's RTX-30 Founders Edition cards. It's almost certain to debut with Nvidia RTX-40 and AMD RDNA 3 cards.

That 600W capacity doesn't bode well for future GPU power consumption. Some internet rumours indicate that high-end next gen cards could use all of that. That's a disturbing number for several reasons, but that's a tale for another Two Bits.

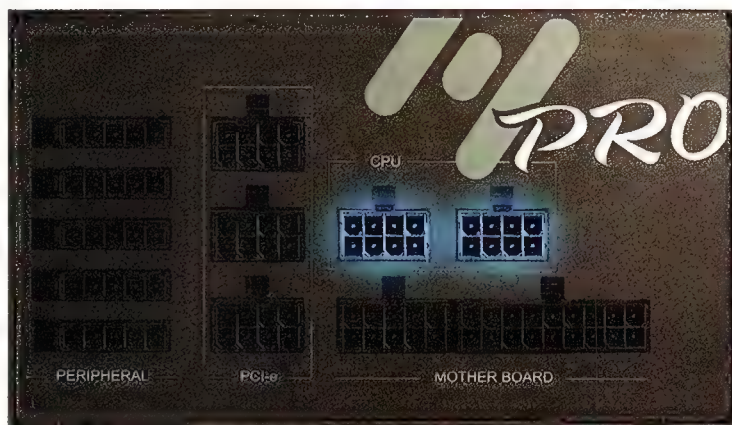
The new connector will certainly help for lovers of clean builds. Having up to three 8-pin power connectors adds clutter and leaves you with more cables to route. They're a legacy of years past when the idea of 400 W+ GPUs was inconceivable.

ATX 3.0 isn't all about GPU power. The ATX12VO 2.0 spec introduces some other features including better reliability, tolerance for power spikes and particularly welcome changes to low load efficiency, which is a weakness of even the most efficient of today's PSUs. Low load efficiency improvements are designed to help the PC industry meet ever stricter governmental energy regulations. OEMs and system integrators are increasingly being required to reduce desktop idle power consumption. Efficiency above 60 percent is required for 10W or two percent of maximum capacity, while above 70 percent is recommended.

Interestingly, ATX 3.0 PSUs will



CHRIS SZEWCZYK
A life-long PC tech enthusiast, Chris has worked across the industry in many areas as a product and technology expert.



introduce a new certification standard by Cybernetics alongside the existing 80 Plus ratings. Cybernetics certifications aren't just for efficiency. There's also a noise level certification and a tangentially related chassis soundproofing certification that will definitely assist users that want a quiet build.

What's not certain is if next-gen cards can be used with current power supplies. A high quality unit can potentially power a next gen GPU, but without those extra signalling pins, can they be used with adapters? I'm sure this will be a hot topic over the coming months. Expect forums to be filled with "Will my PSU be able to run my

PCIe 5.0 graphics card?" To prevent the possibility of headaches, you're best off waiting to see what the PSU manufacturers say. We should find out long before the launch. I hope current PSUs aren't suddenly made obsolete.

MSI has already launched its Creator P100A and MPG Trident AS ATX12VO systems. Both come with an ATX12VO-compliant PSU. We can expect PSU manufacturers to release updated designs throughout 2022. With that in mind, buying a high-end power supply makes no sense right now unless you're not planning to upgrade for some time to come. If you want to upgrade to a Zen 4 or 13th Gen system with an RTX-40 or RDNA 3 GPU, definitely hold off buying a PSU for now. ■

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Backing the blockchain

Big fish Intel enters the mining pool.

Perhaps a sign of the coming cryptapocalypse, Intel recently disclosed that it has been testing the waters for mining ASICs for years. It also revealed its first-generation BMZ1, codenamed Bonanza Mining, and looked ahead to BMZ2, its second-generation chip that will be manufactured on a cutting-edge node rather than the 14nm process used for BMZ1. Most surprisingly, it was noted that BMZ1 was created as a 'product exploration' in 2018.

The initial BMZ1 foray into cryptocurrency mining took a similar approach to other Bitcoin ASICs, packing about 137 GH/s of SHA-256 hashing power into a chip that measured just 14.2mm². That tiny die size means Intel could get around 4,000 chips from a single 300mm silicon wafer. While the hashrate of a single chip is nothing special,

modern Bitcoin miners use hundreds of chips placed on larger circuit boards. BMZ1 already delivered an efficiency rating of 18.2 W/TH, which compares favourably to Bitmain's S19 Pro ASIC with an efficiency of 29.5 W/TH. How BMZ1 would scale to larger mining solutions isn't clear, but considering the S19 Pro uses TSMC's N7 process, the fact Intel delivered higher efficiency using its 14nm node suggests Bitmain and other ASIC companies should be worried.

It's not just the performance, of course. One of the big issues with mining ASICs is their prohibitively long lead times, and the fact that companies such as Bitmain and MicroBT often change prices according to the current value of Bitcoin. Since they are smaller players in the global chip market, competing



JARRED WALTON
Jarred Walton has been a PC and gaming enthusiast for over 30 years.

for wafers at TSMC and other foundries, supply can be a bit less predictable. Intel owns a lot of chip fabs and has much higher volumes from its CPUs. It could put out a lot of 14nm BMZ1 chips and conceivably offer better pricing to big mining firms.

That appears to be the path forward, as one large mining firm, Grid Infrastructure, has apparently inked a contract where it will purchase 25 percent of Intel's mining ASICs through 2025, with fixed pricing through 2023. Grid has plans to go public with an initial estimated valuation of \$3.3 billion, and it intends to operate three mining facilities totalling 734 megawatts of power by 2023. Other mining firms that will use Intel's chips include Argo Blockchain and BLOCK (formerly known as Square).

Intel hasn't said exactly what we can expect from BMZ2, but rumours are it will use TSMC's N5 process. Assuming a similar chip size to BMZ1, it could potentially double the hashing power within similar power constraints. But Intel's competitors aren't sitting still. There are already rumours of Bitmain's S19 XP, using TSMC N5 too. Except, it's said that S19 XP will only reach an efficiency level of 21.5 W/TH, something Intel already does on its own 14nm node.

Intel's Raja Koduri, head of the Accelerated Computing and Graphics Business Unit, wrote about the emerging importance of blockchain technologies. "We are declaring our intent to contribute to the development of blockchain technologies, with a roadmap of energy-efficient accelerators. Intel will engage and promote an open and secure blockchain ecosystem and help advance this technology in a responsible and sustainable way." If you were hoping blockchain and mining would fade away, that's not likely to happen any time soon. Let's just hope more of it migrates away from using graphics cards. ■

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Intel's BMZ1 chip, codenamed Bonanza Mining, is optimised for Bitcoin's SHA-256 algorithm.

When you realize that
1970 and 2022 are as
far apart as 1970 and
1918 I'm just
going to need a
minute



- Like Comment Share
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- Heather Hulme Santamaria
Uh ... no... can't be.... Where's the
'new math' when you need it?!!
Like Reply 5m
- Sis Richner
Wow, hard to grasp this
Like Reply 6m
- Annelies Nyburg Vanderkamp
I'm sorry... What???
Like Reply 6m
- Chris Hill
Oh my...how time flies
Like Reply 6m
- Deb Kind
Yup at least a moment !!
Like Reply 6m
- Write a comment...

ONE MORE THING

Our accelerated epoch

An age-old meme transports Jon Honeyball from the first years of the home computer back to horse-drawn carts.

I don't normally take much notice of the memes that clutter up timelines on Facebook and Twitter, but this one made me pause: 1970 to 2022 is as far apart as 1970 and 1918. I remember 1970. I was six at the time, and 1970 was just before the computing world burst out from the industrial confines of the mainframe and minicomputer and into the era of home computers.

Apple unveiled its first computer in April 1976, while the Sinclair ZX80 arrived in February 1980. IBM was famously late to the game with its epoch-defining Personal Computer in 1981, and we had to wait until the Lisa (1983) and Macintosh (1984) for anything resembling the graphical user interface we've become so used to.

But then we were off. Intel set the pace, with its 16-bit 80286 processor introduced in early 1982 and the 32-bit 80386 arriving in late 1985. It's hard to comprehend just how much has changed since then, and how rapidly. Those of us of a certain age still manage to get our megabytes and gigabytes of

RAM muddled up, because we remember the wallet-emptying pain of upgrading an early 80386 computer from 8MB to 16MB.

Now let us cast our mind back to the same 52-year time span, but from 1918 to 1970. My grandfather was born in 1905, so he was an early teenager at the end of the First World War. He was the last in a line of bakers in the village that stretched back hundreds of years. They still had a horse and cart to deliver the bread around the villages.

By 1970, we had television, telephony, radio and a range of newspapers and magazines. I remember my dad making a business call to New York around 1970, a call that had to be booked via the operator to get a time allocation on the transatlantic landlines. The changes from 1918 to 1970 were hardly small – the mass adoption of the motorcar, for example, let alone all of the changes in housing, social care and welfare. But I can't believe that this rate of change is in any way comparable to that which has happened from 1970 to 2022.

This leads to the obvious question. What will things be like



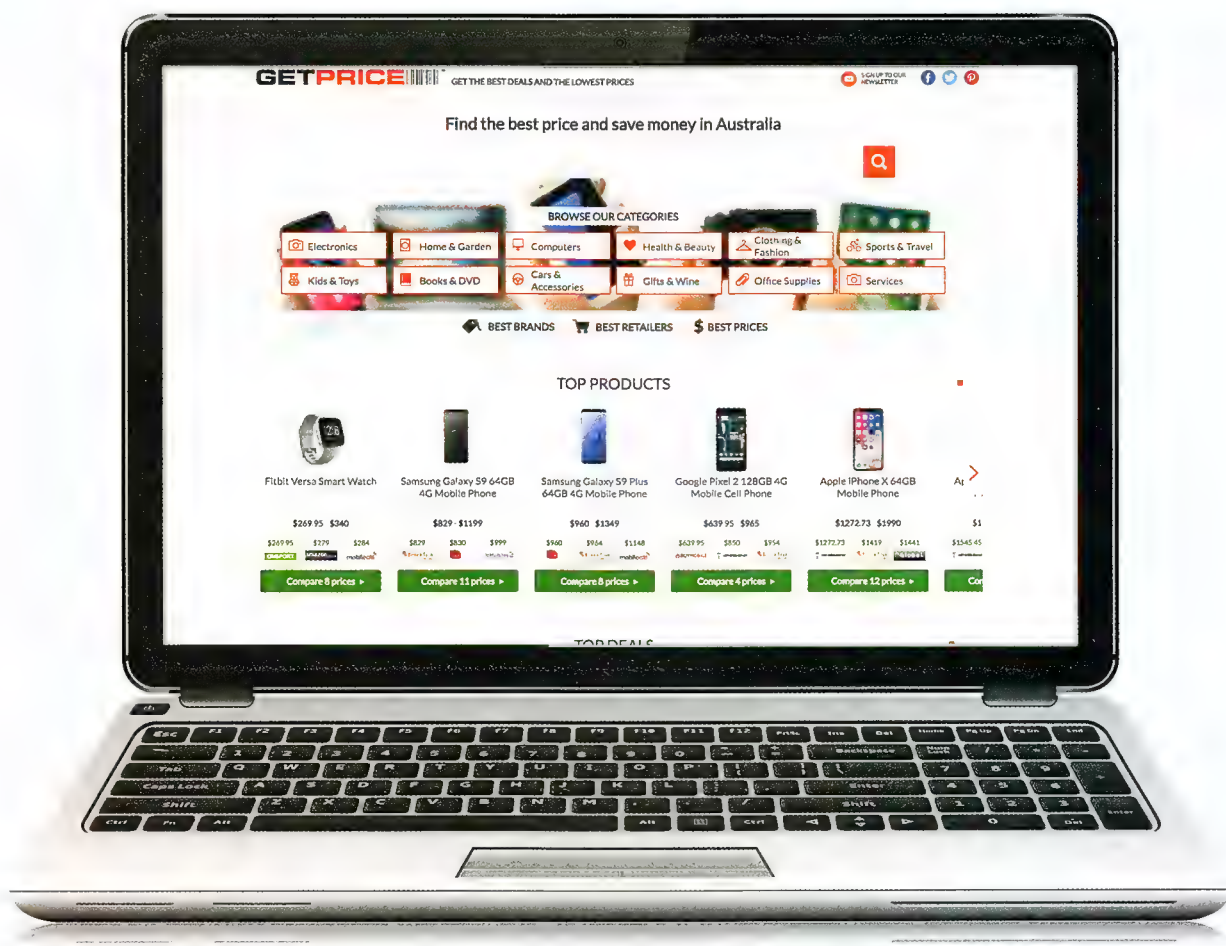
JON HONEYBALL

Jon Honeyball accepts that the grey hairs that have appeared are God's way of telling him he is old.

in another 52 years, by 2074? I fear we will have access to everything, everywhere at all times. Privacy will be dead and buried. People will become more insular and inward looking, preferring the triviality of the metaverse over the harsh reality of daily life in a world blighted by global warming. The new invention of "turn on, tune in, drop out" of society.

Will we have descended to the depths of *The Matrix*? I hope not, but my fear is that the sociopathic leeches at the global social media platforms have already started us on the journey. And my contempt could not be higher for the real-time advertising brokerage system, built upon a belief that media networks have an inalienable right to know everything about everyone.

I'm sure that if my grandfather, William Oliver, was around today, he would find much of it confusing and baffling, but still something he could relate too. I am not sure a 110-year-old me would be as well-adjusted in 2074. Indeed, I am quite certain I would be terrified. ■



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NEW IN
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FRIGHTENING FUTURE?

Five scary ways technology is being used now

Future tech can be scary. Nicole Kobie reveals five nightmarish use cases of drones, AI and more – and ways such tools are being used for good.



Robots. Drones. AI. Whenever a new technology creeps into the public consciousness, we can't resist considering its potential in extremes: smart city tech will either be a clean, convenient utopia or a centrally controlled dystopia. The positive vision is often pushed by venture-capital investors, startup marketing teams and over-eager journalists, while the nightmare view is heralded by activists, regulators, overly cynical journalists – as well as in science fiction shows such as *Black Mirror*, created by Charlie Brooker.

The reality for most technologies is somewhere in between those extremes, and largely dependent less on the innovation itself than how we humans choose to make use of it. Self-driving cars should reduce accidents, but could require pedestrians to be sequestered away from roads. AI may help cure cancer, but it could also exacerbate inequity. Robots reduce the human cost of industrial accidents, but may spark mass unemployment. Facebook lets you share baby photos to far-flung relations, but is contributing to the downfall of democracy – okay, maybe that last one is a bad example.

It's a cliché that technology is

just a tool, but there's no question that a hammer is less frightening when it's tapping in a nail to hang a family photo than when it's being brandished in rage at your face. Here are five ways future technologies are being trialled now in frightening ways – and, to avoid causing too many nightmares, a few more cheerful use cases for such innovations.

01 Crowdsourcing public services

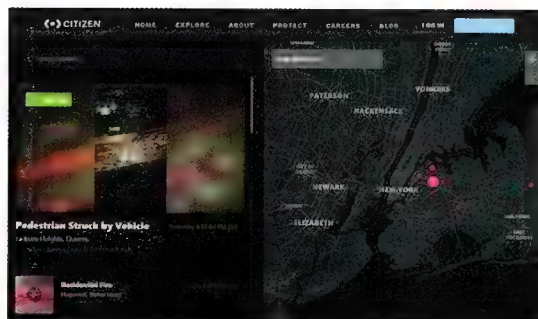
To help explain what the "Citizen" app does, it's useful to know that it was originally called "Vigilante". The "personal safety" app gathers up crime information from official alerts, police scanners, and videos from local users, helping to find missing people, speed up responses to incidents, avoid crime

The Citizen app gathers local crime information.

as it happens and – according to the website – help track lost dogs. The app even includes severe weather alerts.

That may sound like little more than a neighbourhood watch app, but Citizen has been controversial for how the information shared is used, including criticisms that it leads to false alarms, incites mobs and encourages racial profiling. Last year, an alert went out on the app about a wildfire near LA, including the name and photo of the person accused of starting it – and a \$30,000 reward for information. That person was arrested, though eventually deemed innocent; another man was eventually arrested. Citizen said in a statement at the time that it retracted the photo and reward when the error was realised, and that the mistake was taken seriously.

The service is now expanding its remit. Citizen's \$20-a-month Protect subscription service lets users call for help via the app, connecting them with "virtual agents" who will call emergency services on your behalf with your location if deemed necessary. The Protect service also has a feature called "citizen incident creation" that lets those in need ask for help



from nearby users.

While the examples on the website are admittedly benign – helping to find that lost dog, pinpointing the location of missing hikers – Citizen has also tested a system to send out private security guards, though this iteration of Protect doesn't include that option. How such systems are used is key: it's one thing hiring private police or gathering a mob of locals to track down your lost dog, another to tell them to hunt down suspected criminals, potentially putting innocent people at risk.

There are positive ways that crowdsourcing apps can be used to truly help without all the controversy. Apps such as PulsePoint in the US and GoodSAM, which is active in most countries including Australia, are designed to get useful first aid to people having a heart attack, sending out emergency notifications to anyone trained with CPR nearby as well as revealing the location of nearby defibrillators. The faster someone starts resuscitation on someone having cardiac arrest, the better their chances of survival.

02 Drone police

ShotSpotter is an American company that uses AI to listen out for gunshots, allowing police to get to the scene of an incident more quickly than if they waited for members of the public to call in – and often they don't, for various reasons. That raised concerns on its own: though some police forces say the technology helps them target gun crime, and it's been used in more than 200 court cases, a study from MacArthur Justice Center questioned its accuracy, another published in the *Journal of Urban Health* suggested the technology had little impact on gun crime, while an investigation by tech site *Motherboard* revealed the listening tech is almost entirely used in black or ethnic majority communities.

Meanwhile, Chicago authorities are investigating the use of the technology by local police after it picked up a firework as a gunshot, leading to an apparently innocent man held in jail for a year on murder charges. That man, Michael Williams, has since been released on grounds of insufficient evidence. "I kept trying to figure out, how can they get away with

using the technology like that against me?" Williams told the Associated Press. "That's not fair."

The system is adding response automation thanks to a partnership with Israeli firm Airobotics, which will see that firm's drones sent out to locations where gunfire is detected in order to take photos and supply live stream video to police. In other words, the first responders to a shooting may well be AI-flown drones.

That potentially increases the automated surveillance in those predominately non-white communities, exacerbating bias concerns and the risk of wrongful arrest that Williams experienced, though the companies argue that the combined technologies are merely tools to help police rather than replace them. In short, any fault should lie with human officers using such tools rather than machines or developers, but with police under increasing scrutiny, that may not convince many.

On the upside, if you're the person who's been shot, argues ShotSpotter, at least you may get found sooner. "Every second counts, and our alerts combined with Airobotics 'eyes in the sky' increase the likelihood of locating a victim and saving their life, finding critical evidence and more proactively addressing gun violence in Israel," said Ralph A Clark, CEO of ShotSpotter, in a statement launching the partnership.

Always-listening sensors and

Listening in: using drones to identify gunshots has proved controversial.

autonomous drones make for an intimidating policing scenario, but the same core technologies are also being used to track wildlife and protect them from poachers around the world. In one example, the University of Southampton worked with Marwell Zoo in the UK to build drones with noise sensors to better identify wildlife such as zebras and rhinos from the air, helping to increase the accuracy of monitoring without annoying the animals.

03 Deepfakes

It's already difficult to trust what we read and watch online, but deepfakes are set to make it so much harder. Deepfakes are already here, and they're getting more convincing. It's already possible to add a false face to someone in a video or change the audio so they appear to say whatever you'd like. So far, we've seen Mark Zuckerberg apologising for stealing data, Jon Snow admitting the last season of *Game of Thrones* was disappointing, and Barack Obama calling out Donald Trump – all were fake, but looked and sounded convincing thanks to AI. Deepfake techniques have been used to make the Mona Lisa smile and to write convincing text, potentially automating trolling and misinformation.

So far, deepfakes have largely been used to create pornography, slapping someone else's face onto a porn star's body – indeed, a study by security firm Deeptrace suggested 96 percent of deepfakes



On the plus side, drones are being used to protect wildlife from poachers.



online are sex related. As nefarious as that is, the wider concern lies with our increasing inability to trust what we see, and the impact that could have on our society and democracy.

That's the case even if the video in question isn't a deepfake. A Brazilian politician allegedly caught in a compromising position on video in 2018 claimed the clip was a deepfake, a successful tactic as there was no evidence either way. That may point the way to a solution: as deepfakes proliferate, we'll need tools to identify authentic from fake, potentially sparking an arms race of AI editing.

Of course, applying AI to photo-editing tools does have its upsides, letting those of us without Photoshop skills finally clean up our photos easily. For example, Google last year rolled out an upgrade to its Photos app for Pixel phones that uses machine learning to remove annoying objects from the background of images.

Indeed, smartphone photography is so good largely because of algorithmic processing that does the work that used to be done manually on a much more complicated camera.

04 Slaughterbots

Videos of Boston Dynamics' military robots have long been staples of the web, whether it's blooper reels of clumsy stumbles for laughs or terrifying demonstrations of genuine skills such as running at speed or climbing through windows into buildings. While letting robots loose on a battlefield

is a concerning enough proposition, and drones have already been used in military conflict in Libya, what happens if the technology becomes cheap and easy enough to use by everyone – including criminals?

That's the premise considered by academic and activist Max Tegmark of the Future of Life Institute at MIT, warning in a video of the potential rise of "slaughterbots", such as drones equipped with facial recognition and armed with guns.

Such a weapon could be used to rob banks or target voters in poll queues, and even by gangs or cartels for retribution or assassination. While the UN is calling to regulate lethal robots, it's not as though criminals and terrorists will bother to comply with such treaties, even if they can be agreed.

Horrorifying though it is, the use of "slaughterbots" is naturally a worst-case scenario. Though nightmare-inducing, so far robots and drones have unquestionably saved lives by reducing industrial accidents and taking over monitoring in dangerous conditions, such as offshore oil rigs.

The University of Warwick, for example, recently revealed HausBots, a wall-climbing robot designed for inspection and maintenance such as painting, with the aim of reducing the risk to human workers.

In the future, we may be mugged or murdered by a slaughterbot, but at least machines will paint our houses for us first.

HausBots is a wall-climbing robot designed for inspection and maintenance.

05 AI law

Anyone looking to use artificial intelligence in the justice system should by now be wary, with infamous cases of facial recognition leading to the arrest of the wrong man and sentencing algorithms shown to have racial bias. Despite such concerning incidents, researchers in China have developed an AI prosecutor and tested it with a local prosecution office, claiming a 97 percent accuracy rate when filing charges with eight specific crimes, including fraud and dangerous driving – as well as "picking quarrels and provoking trouble", which reports suggest is used to arrest people for political dissent.

Known as System 206 – perhaps it sounds less like a sci-fi villain in Mandarin? – the AI was trained on 17,000 cases to help file charges based on a verbal description of a case. The aim isn't to replace prosecutors entirely, but to remove one job to help cut their workloads. "The system can replace prosecutors in the decision-making process to a certain extent," said the researchers in a paper published in *Management Review*.

Such a system raises a host of concerns, many of which will be familiar criticisms of AI: who is responsible for mistakes; will the system embed existing biases and errors, given it's trained on existing cases; and will this limited use of filing paperwork soon extend to more serious decision making? So far, human prosecutors remain in control, but with AI increasingly in use across China's justice system and the rise of its infamous social credit system, automating the punishment of minor infractions seems just a few steps down a slippery slope.

On the other hand, automation can help individuals push back against government bureaucracy in the justice system. Look at DoNotPay, a legal chatbot created by Joshua Browder to battle parking tickets by making it easy to decide whether you should contest the fine and help file an appeal. From such humble beginnings, DoNotPay has expanded to include automated legal services on everything from setting up power of attorney to getting compensation for cancelled flights, agreeing a divorce settlement, and filing a defamation lawsuit. ■



DoNotPay, a chatbot that helps you contest parking fines.

NBN OUTAGES: WHAT YOU CAN DO WHEN YOUR INTERNET GOES DOWN

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Live life smarter



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05

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The A-List

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PREMIUM LAPTOPS

Apple MacBook Pro 14in

Stunning creative power from \$2,999

apple.com/au

Alongside its 16-inch sibling, this is simply the world's best laptop for demanding users. The amount of power on tap via the M1 Pro or M1 Max processor is staggering, and it's backed up by a terrific screen and stunning battery life. With all the ports you could ask for, the only negatives are its relative bulk (especially compared to the Air) and high price.



ALTERNATIVES

Samsung Galaxy Book Pro (15.6in)

A powerful laptop with a 15.6-inch AMOLED screen that weighs a mere 1.05kg? And with stonking battery life too? The Galaxy Book Pro is a winner.

Core i5, \$1,333, amazon.com.au

Apple MacBook Air

If you don't need the power of an M1 Pro or M1 Max, "make do" with the M1 in the MacBook Air and enjoy its super-slim design and relatively light weight at a much lower price.

From \$1,499, apple.com/au

LG Gram 17 (2021)

The combination of a 2,560 x 1,600 17-inch screen and 1.3kg weight – as well as a well-rounded specification – make this a great buy for homeworkers.

\$2,998, lg.com

GAMING LAPTOPS

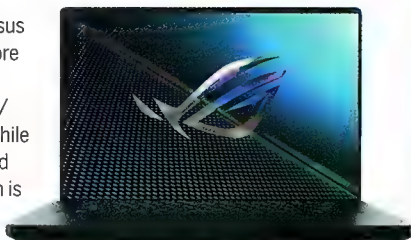
NEW ENTRY

Asus ROG Zephyrus M16 (2022)

i9-12900H and an RTX 3070Ti

asus.com

2022 will see an update for all mainstream gaming laptops, and Asus is first to jump in with a 12th gen Core i9 CPU to give 16-core support to the RTX 3070 Ti graphics (a Core i7/RTX 3060 variant costs \$2,999). While battery life is only average at around six hours, this laptop's final triumph is fitting a gorgeous 16-inch screen into such a compact chassis.



ALTERNATIVES

Asus TUF Gaming A15 (2021)

The TUF Gaming A15 is a great choice if you need both power and portability, thanks to a Ryzen 7 5800H processor and RTX 3070 graphics. \$2,399, asus.com

Asus ROG Zephyrus S17 GX703

The combination of RTX 3080 graphics and Intel's Core i7-11800H CPU in our test model led to predictably blistering performance. \$5,399, asus.com

Lenovo Legion 5 (Gen 6)

An RTX 3070 is the star, but it's backed by a high-quality 15.6-inch 165Hz screen, Ryzen 7 CPU and a solid aluminium chassis. \$2,299, asus.com

BUSINESS LAPTOPS

Dynabook Portégé X30W-J

The best convertible money can buy

\$2,369, asia.dynabook.com

Not only is this 2-in-1 convertible ludicrously light and slim, but it also offers a quiet keyboard, performance fireworks, ports a-plenty, a natural-feeling touchscreen and a battery that will see you through a busy working day. Dynabook by name, dynamite by nature.



ALTERNATIVES

Lenovo ThinkPad T14s

Solid, dependable and a pleasure to use, the powerful and slimline ThinkPad T14s includes a new Ryzen 7 Pro, as well as a super-plush keyboard. \$1,749, lenovo.com/au

Lenovo ThinkPad X1 Carbon Gen 9

A business laptop with heaps of luxury, especially if you choose the top-end model with a 3,840 x 2,400 screen. \$2,389, lenovo.com/au

Dell XPS 13

Dell has updated the gorgeous XPS 13 with Intel's 11th-generation Core chips to great effect. The 13.4-inch screen, touchpad and solid keyboard are similarly sumptuous.

From \$1,518, dell.com

EVERYDAY LAPTOPS

Acer Swift 3X i7

Excellent performance at an appealing budget price.

acer.com

The headline feature of Acer's new Swift 3x is undoubtedly the fact that it features Intel's new discrete GPU – the Iris Xe Max Graphics. The Swift 3x is available exclusively through Harvey Norman as either an i7 with a 1T SSD, or a Core i5 model, with a 512GB SSD.



ALTERNATIVES

Lenovo Yoga Slim 7 Pro

A powerful, well designed ultrabook with an awesome OLED screen for a good price. The original 2-in-1 bends into a new clamshell shape. \$1,949, lenovo.com

HP Envy 13 (2020)

It may not be the world's most exciting laptop, but the Envy 13 is a compact and forward-looking machine that's ideally suited to these homeworking times. \$1,699, store.hp.com

Microsoft Surface Laptop Go

A superb travelling companion, the Go offers all the power you need in a stylish and well-built 1.1kg chassis. 128GB, \$1,179, microsoft.com

CHROMEBOOKS

Asus Chromebook Flip C436F

Flexible laptop for \$1,419

amazon.com.au

The Flip C436F is a fast, flexible laptop with a slim magnesium alloy chassis that's easy on the eye. With a 256GB SSD, a Core i5 processor and fantastic 14-inch Full HD screen, it's a fine choice for demanding users.



Asus Chromebook CX9

Aimed squarely at business users, this exceptionally quick machine – with a Core i7 processor, 16GB of RAM and a 512GB SSD – drips quality throughout its aluminium alloy chassis. Add a glossy 4K 14-inch screen, plus a low weight of just 1.05kg, and it justifies its high price.

\$1,579, asus.com

Lenovo IdeaPad Duet

The Chromebook answer to Microsoft's Surface tablets, this is a seriously versatile device – albeit not the speediest (although we never found it to be painfully slow while carrying out everyday tasks). For this price, and with a 16hrs 14mins battery life, the Duet is a great choice.

\$447, lenovo.com

TABLETS

Apple iPad Pro 12.9in (2021)

M1 power in your palm from \$1,199

apple.com/au

Blurring the boundaries between laptop and tablet like never before, the M1-powered iPad Pro 12.9-inch is every bit as fast as we expected – and the "Liquid Retina XDR" display is simply phenomenal.



Apple iPad (2021)

Apple performs its usual trick of upgrading just enough to keep the iPad affordable and up to date, without treading on the toes of its more luxurious stablemates. The big bezels remain, but a faster processor, more storage and improved camera all add to its appeal.

From \$449, apple.com/au

Samsung Galaxy Tab S7

If you want a cheap Android tablet, get a Kindle Fire. If you want quality, choose the sumptuous Galaxy Tab S7. In return for your outlay, you receive top-quality construction, a stunning 120Hz 11-inch display, plenty of power and a nifty stylus in the box. If only Apple was as generous.

\$949, samsung.com

EVERYDAY MONITORS

Philips Brilliance 346P1C

34-inch curved docking, \$849

philips.com.au

No-one can match Philips for its mix of quality, features and value, especially when it comes to curved MVA monitors such as this. It's great for casual gamers and busy workers alike, with USB-C docking and superb colours.



Eizo FlexScan EV2480

Businesses in particular will love this easy-to-roll-out 24-inch monitor, with its exceptional five-year warranty, USB-C port for easy docking, excellent viewing angles and delicious whites. And it has the best OSD around.

\$699, eizoglobal.com

Dahua DHI-LM28-F420

This affordable 4K monitor might not offer much in the way of menu options or high-end gaming perks, but it offers impressive resolution and colour for a fraction of the price you'd normally pay.

\$269, dahuaaustralia.com.au

PROFESSIONAL MONITORS

Eizo ColorEdge CG319X

Creative masterclass, \$7,119

eizoglobal.com

As the price indicates, this monitor is for heavyweight creatives who demand the best in every discipline: HDR video editing, print layouts, professional photography and more besides. With superb coverage and accuracy across all spaces, plus a built-in calibrator, it justifies the investment.



BenQ PD2725U

By no means a cheap 4K 27-inch monitor – unless you compare it to the Eizos – but it marries all-round quality with ease of use thanks to a puck that allows you to quickly move between settings. You can even daisy chain a second Thunderbolt 3 monitor for a monster setup.

\$1,799, benq.com

Eizo ColorEdge CG279X

Designers who need to work across different disciplines will love how easy it is to switch between the Adobe RGB, DCI-P3 and sRGB colour spaces using the Eizo's fantastic OSD. It's certainly not cheap for a 27-inch 1440p monitor, but it's packed with quality.

\$3,095, eizoglobal.com

HOME OFFICE PRINTERS

NEW ENTRY

Epson EcoTank ET-1810

Back to basics

\$299, epson.com.au

There's nothing flashy about this bottle-fed inkjet: it's there to churn out pages at a decent rate (8.8ppm for black text) for a low price. It comes with enough ink for 4,500 black pages and 7,500 in colour, but refills are cheap. Just don't expect features like duplex printing.



Canon Pixma Pro-200

Yes, it's big and it's expensive – and you don't even get a scanner – but the Pixma Pro-200 means that you can print A3 photos with glorious colour accuracy and detail. If you're after an office workhorse, look elsewhere, but it can't be beaten on photo quality.

\$809, canon.com

Brother MFC-J4540DWXL

Home workers will love this inkjet all-in-one. It combines an incredible range of features with all the connectivity you need and extreme ease of use. Output quality is fine, it offers the best cloud support around and the high-capacity ink pack could keep you going for years.

\$420, brother.com

WIRELESS ROUTERS

Asus Zen Wifi XD6

Winning Wi-Fi 6 performance, \$699

asus.com

Asus continues to refine its Zen Wi-Fi 'megamesh' routers (two nodes with a dedicated backhaul channel) and, with the XD6, produced the fastest overall router we've ever tested.



Asus RT-AX82U

The impressive RT-AX82U punches well above its price when it comes to raw Wi-Fi 6 performance and includes a fistful of useful features – such as an ultrafast 20Gbits/sec USB connector, outbound VPN support, site-blocking and a host of parental controls. **\$320, asus.com**

Huawei WS7200

This affordable Wi-Fi 6 router delivers consistently fast wireless speeds, broad coverage and a modest speed boost for newer hardware – and the Router 3 has a cute design too. If you need more range, you can pick up a second unit to use as an extender. **\$120, huawei.com**

MESH WI-FI

Netgear Orbi RBK752

Wide Wi-Fi 6 mesh, \$669

netgear.com.au

More expensive rivals may boast better performance, more connections and a more impressive selection of features, but the user-friendly Orbi RBK752 offers unimpeachable mesh coverage for the price.



TP-Link Deco X20

The price below isn't a typo: the Deco X20 makes it possible to upgrade your home network to Wi-Fi 6 – as well as manage its security – for the price of some standalone routers. The included HomeCare functions are also a great bonus for households where lots of devices are fighting over the bandwidth. **\$199, tp-link.com**

Asus ZenWiFi AX

The interface and design certainly aren't the prettiest (the nodes look like mini space heaters, while the charcoal version is straight out of the 1980s), but if you're after strong performance, great features and plenty of expansion potential, the ZenWiFi AX is a compelling prospect. **\$949, asus.com**

NAS SERVERS

Synology DS218+

Two-bay NAS, \$652

synology.com

The Synology DS218+ is the best two-bay NAS server around, thanks to a dual-core Celeron that gives it some added grunt, an intelligent design that makes adding disks a piece of cake and a wide-ranging spread of apps.



Asustor Nimbustor AS5304T

This is a hugely powerful four-bay NAS that will be overkill for most people – not just due to its speed but also its slightly intimidating user interface – but techies and gamers should investigate the Nimbustor AS5304T for both its speed and flexibility. **\$799, asustor.com**

Synology DS1019+

This five-bay NAS includes many of the features that make the DS218+ to the left such an attractive buy: a superb selection of apps, an elegant hardware design and a good deal of power. And those five bays make it perfect for RAID5 configurations, or Synology's own Hybrid RAID. **\$1,249, synology.com**

SECURITY SOFTWARE

F-Secure Safe

F-Secure concentrates on the basics: faultless protection with minimal impact on your system's performance – for a low price. **1-3 PCs, 1yr, \$99.99, f-secure.com**



VPNs

NordVPN

NordVPN provides consistent and fast speeds, serious security, great support for video-streaming services and some cost-effective subscription rates. **\$59 per year, nordvpn.com**



NordVPN

Kaspersky Internet Security

With plenty of tools and features to play with, the powerful Kaspersky Internet Security goes a long way beyond blocking viruses. **1 PC, 1yr, \$41.95, kaspersky.com.au**

Avast Free Antivirus

For the second year running, Avast is our top pick for free antivirus software – it's simply lighter on its feet than Microsoft Windows Security, whilst offering fewer false positives. **Free, avast.com**

ProtonVPN

ProtonVPN provided one of the best free offerings of all the VPNs in our group test, including unlimited data, but upgrade to benefit from even faster speeds and many more options. **Free, protonvpn.com**

Surfshark

A strong rival to NordVPN, especially if you're willing to commit to its two-year contract. It's fast, cheap and a fine choice for people who like to switch to US streaming services. **\$66.34 for one year, surfshark.com**

PASSWORD MANAGERS

Bitwarden

Bitwarden has a huge advantage: it's free. It isn't as slick as some paid-for rivals, but it can sync passwords across all devices for no extra charge. **Free, bitwarden.com**



Dashlane

A manager that's ideal for beginners, and it even builds in an unlimited (if basic) VPN service. Note you may prefer to buy the Family plan (\$60 per year) as this extends the service to six people. **\$55.99 per year (Premium), dashlane.com**

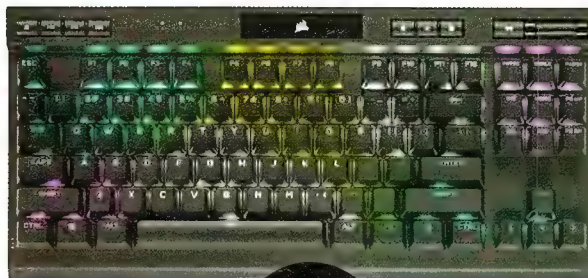
1Password

1Password is targeted at technically minded users who are looking for the last word in security. It even offers a Travel Mode that may ease your mind if surrendering your phone to customs officials. **\$54.99 per year (individual), 1password.com**

THE LIST

The top five TKL keyboards

With respect to all the accountants and spreadsheet wizards out there who couldn't live without their numerical keypads, most gamers find them an unwelcome distraction between the main keys and the mouse. That's why tenkeyless (also known as TKL) keyboards have become so popular recently, especially for those with limited desk space. So, this issue's list focuses on five of our favourite TKL keyboards, aimed at gamers looking for the perfect compact setup.



03

CORSAIR K70 RGB TKL

Available with either Cherry MX Red or Cherry MX Speed switches, the K70 RGB TKL boasts the build quality we've come to expect from Corsair. It syncs with the company's iCue lighting controls and has a switch to enable static lighting so you can focus on your games. **\$200, corsair.com**



05

STEELSERIES APEX 3 TKL

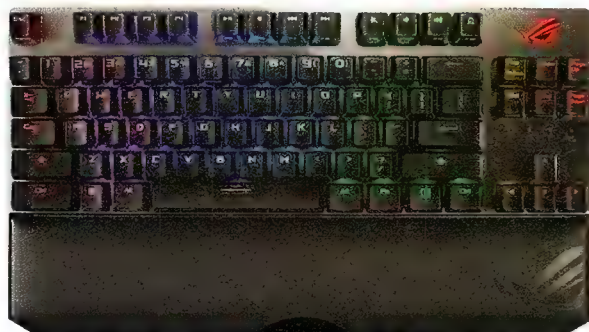
The only non-mechanical keyboard on this list, the SteelSeries is still a fantastic board with lots of features. We love SteelSeries' "Whisper-Quiet" switches that feel great to type on, the dedicated media controls, and PrismSync lighting control, but we don't love the non-removable USB cable. SteelSeries also claims the Apex 3 TKL is the world's first water-resistant TKL keyboard. **\$110, steelseries.com**



02

MSI VIGOR GK50 LOW PROFILE TKL

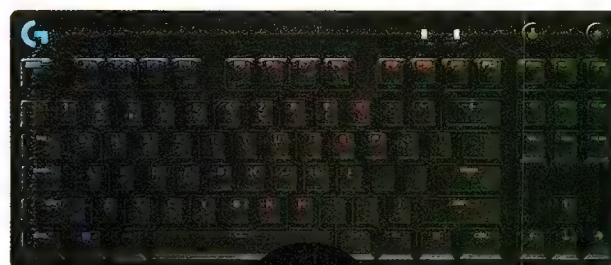
If you like mechanical keyboards but find them difficult to type on, this is ideal. The keys are lower and wider, making it feel more like a laptop keyboard, although the Kailh Low Profile mechanical switches are "clicky" and therefore noisy. At 560g, it also weighs much less than its rivals, making it well suited for travel in its included carry case. **\$140, msi.com**



04

ASUS ROG STRIX SCOPE TKL DELUXE

This Asus uses the popular Cherry MX Red switches. It scores points for having a larger CTRL key for FPS players, a newer-style USB-C connector, and a magnetic wrist-rest included, but it loses out for its lack of dedicated media controls and the overly stylised font on the keys. It also works with Aura Sync and has under-keyboard lighting. **\$170, rog.asus.com**



01

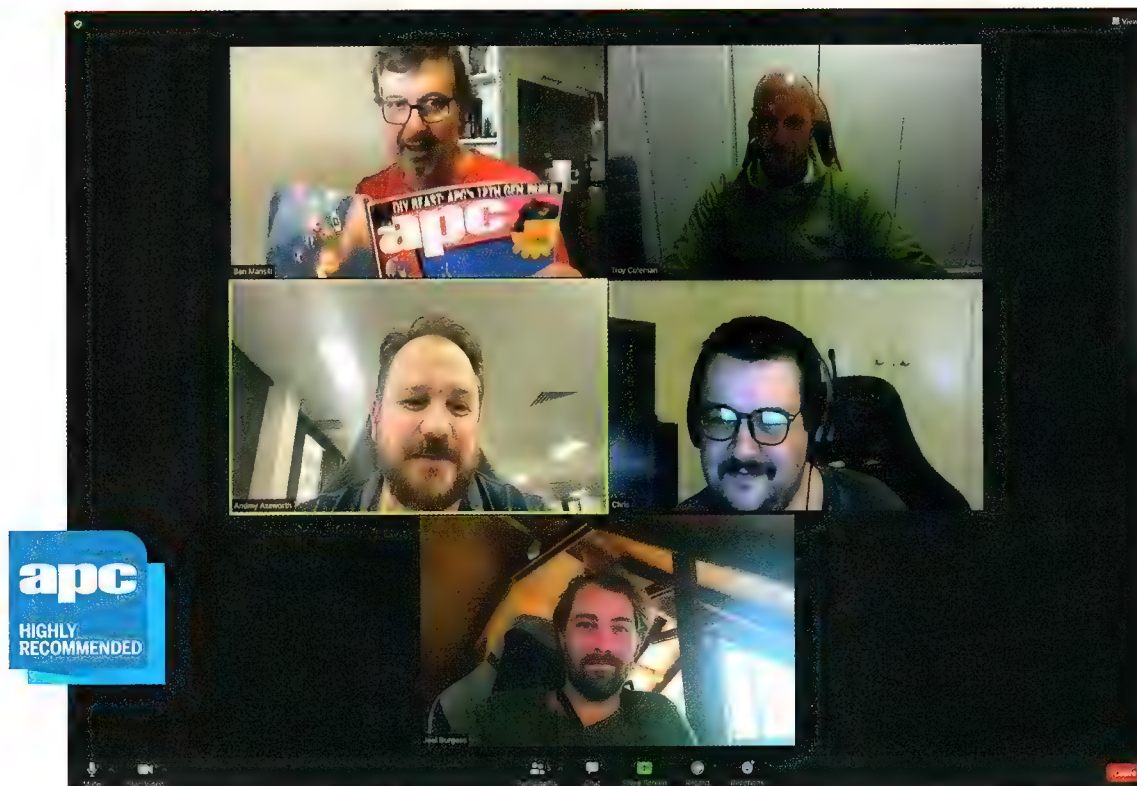
LOGITECH PRO TENKEYLESS GAMING KEYBOARD

Logitech's compact board is a great all-rounder, with features such as button-based lighting control and a game mode button to disable the Windows and Menu keys while gaming. If Logitech's Blue "clicky" switches are an issue, the Pro X model costs \$30 more and lets you swap out switch types. **\$150, www.logitechg.com**



HEAD TO HEAD

THERE CAN ONLY BE ONE.



LEFT: Zoom took video calling by storm during the pandemic and it continues to be one of the leading platforms today.
RIGHT: Google Meet offers a clean, icon-based design and has grown rapidly in popularity over the past two years.

ZOOM Zoom Basic \$free, Zoom Pro \$21/month, Zoom Business \$28/month, Zoom Enterprise \$28/month. | www.zoom.com

GOOGLE MEET Google Meet \$free, Google Workspace Individual \$8.40/month, Google Workspace Enterprise (contact company for pricing). | meet.google.com

Zoom vs. Google Meet

Two video conferencing services, which is better?

Over the past decade, the proliferation of camera-enabled devices and free video calling platforms has made video conferencing accessible to all. Even your grandparents have probably been getting in on the act. Of course, the pandemic really kicked things up a gear but, even as life slowly returns to normal, we're still heavily reliant on the technology. Whether it's business meetings, remote working, or family gatherings, video conferences kept our lives going during a tricky couple of years. And now we've gotten used to it, that doesn't look like it's going to change.

Video conferencing is nothing new, and the concept has been around for a while. At the 1964 World's Fair in New York, Bell Labs introduced its new invention, the Picturephone. This device was a 5-inch black and white screen

paired with a camera. For \$16, you got three minutes in a public booth in New York, Washington DC, or Chicago and the ability to connect with another Picturephone user. Of course, at nearly \$145 in today's money, the technology was simply far too costly to catch on.

It wasn't until AT&T's Videophone 2500 in 1992 that video calling became feasible. The colour video was transmitted over a regular phone line and didn't cost the user any more than a typical phone call. However, it was the arrival of the internet that was the real driver behind the video calling boom.

Skype was one of the first applications, becoming so popular during the past decade that it is now a byword for video calling. As the technology snowballed, many similar applications were created that we still use today – the likes of FaceTime, which

brought portable video calling to the mainstream, plus Google Hangouts, Microsoft Teams, and many more. Two of the most popular video conferencing services are Google Meet and Zoom. These two have been most prevalent in the last few years and both have personal and commercial uses. But the question is, which should you choose?

While our first impressions of software are usually formed on the basis of the user interface, there are two major differences between Google Meet and Zoom. The former is browser-based, while Zoom is application-based. There are pros and cons to each when it comes to design. Typically, a dedicated application makes the experience feel more polished. Zoom has more scope for the user to tweak the size of the window, for example, while its application homepage is well laid out, making it easy to start or join a video call.

However, Google Meet has a clean aesthetic across the board. Keeping things clear and easy to navigate, while avoiding the user interface looking boring is a strong point. This also applies to the design of the calls – Zoom's interface looks cluttered in comparison, as everything is labeled extensively. This makes it easier for newcomers or

In this comparison, we are focusing on the free options of Zoom and Meet, though both also have paid variants with additional functions. Both free versions offer unlimited meetings, Full HD video, screen sharing, layout options, chat, background filters, and a maximum capacity for up to 100 participants.



first-time callers, but once you know your way around the layout, it looks messier than Google's offering. In a Meet call, Google uses a clever range of icons for a cleaner look. The icons are self-explanatory, but you can hover your mouse over them to find out what they do. We would give Google the edge in terms of user-friendliness and overall design.

One of the main reasons for the popularity of these two video conferencing services is the number of features they both offer. Zoom leaped to prominence during the first lockdowns at the start of 2020, when video calls became an essential means of communication. As a result, many businesses opted for Zoom as their go-to service as they could use it for one-to-one chats as well as company-wide meetings. Google Meet didn't quite have the same functions but, two years later, it's fair to say that it has stepped up its game in terms of its functionality.

In this comparison, we are focusing on the free options of Zoom and Meet, though both also have paid variants with additional functions. Both free versions offer unlimited meetings, Full HD video, screen sharing, layout options, chat, background filters, and a maximum capacity for up to 100 participants. For the majority, this will be more than enough. Zoom has more to offer with its free option, as you also get features such as whiteboard, remote mouse and keyboard control, waiting rooms, telephone dial-in, and polls

– quite a step up from Google's offering.

Though Zoom delivers a richer experience, one major positive for Google Meet is that it offers live closed captions. These allow you to receive subtitles for the call, improving the user experience and overall communication. Another key point is that free Zoom calls are capped at 40 minutes, whereas Google's are an hour long. This could be the difference between being annoyingly cut off or not, or might encourage you to make meetings shorter, though that could be a plus for some.

Meet also comes with Google's suite of applications, a huge ecosystem of browser-based tools that are easy to use and access, no matter what device you are on. If you're already a Google user, Meet will keep all your tools in one convenient place.

One downside of Zoom is that you have to download the application. Within the app, there are also third-party apps you can use. The Zoom app store offers a range of group games and the option to add even more functions, but this has caused security concerns. Security and privacy are a vital part of video conferencing, the last thing you want is hackers entering your private business calls. Zoom has had to quickly ramp up its security measures for commercial and domestic video calling.

Meanwhile, Google's security has set the precedent for other online companies. Both services offer encrypted calls, two-factor

authentication, access codes, and also the option to remove unwanted participants from the meeting. So, it's a tie between platforms on security, Zoom wins on functionality, while Google is easier to use and has a crisper design.

Both Zoom and Google Meet are capable video conferencing tools that offer a reliable experience. If functionality is your thing, then go down the path of Zoom, however, for a more seamless experience, we'd choose Google Meet. Google's applications follow a clean and uncluttered style that is up there with the likes of Apple. Meet isn't far behind Zoom when it comes to functions, plus it has more than enough features for the average video call meeting, but the extra call time you get over Zoom and live captions make it a better service. So, Google Meet is our choice between the two and takes the crown as the king of the free video conferencing platforms. The browser availability, clean UI, and ease of use place it above Zoom, making it a more fluent and faster experience.

Zoom

Rich in features, encrypted calls, free dial-in capability, but requires you to download application.

★★★★★

Google Meet

Very clean UI and user friendly, browser based, free live captioning; encrypted calls.

Sam Lewis

★★★★★

GADGETS

NICE LITTLE THINGS

\$TBC | samsung.com

Samsung Odyssey Ark

Big enough for all the animals.

This display behemoth is a mammoth 55 inches across – more than double Apple's largest 27-inch iMac – and uses a heavily curved screen to make using it a little more comfortable and immersive. Like the latest MacBook Pro and iPad Pro, the Odyssey Ark uses Mini-LED tech to ramp up the display quality and offer increased contrast and brightness. You can rotate the screen 90 degrees into a portrait orientation, and thanks to its curvature and enormous wingspan, this makes the monitor loom ominously overhead – to the height of three 16:9 monitors stacked on top of each other, in fact. It's frankly terrifying.

US\$449.99 | polymega.com

POLYMEGA

For an old-school gaming fix.

Old-school games consoles can bring back fond memories and offer up exceptional gaming experiences of their own, but if you're a real enthusiast, a console collection can quickly take up space. The Polymega presents itself as a much better solution, because it's a modular console that plays CDs and cartridges from a really wide range of retro devices. The base model comes with a controller and works with discs from multiple consoles, including the PlayStation 1, Sega Saturn, and Neo Geo CD. You can buy separate modules and swap them for the CD reader on the base model, which then lets you plug in cartridges made for the N64, SNES, Genesis, and others.

\$84.99 | nightwatch.shop

NIGHTWATCH

If Apple's NightStand Mode doesn't quite cut it.

The Apple Watch's Nightstand Mode makes it a bit easier to read the time late at night when your Watch is being charged by using a large font display. But if you struggle to read the screen at night due to poor eyesight or simple tiredness, the NightWatch could help. This is basically a large, bubble-like plastic cover for the Watch, with a curved shell that magnifies your device's screen for easier reading. You can tap the bubble to wake your Watch, and the manufacturer says it will amplify your alarm to ensure you don't miss it.

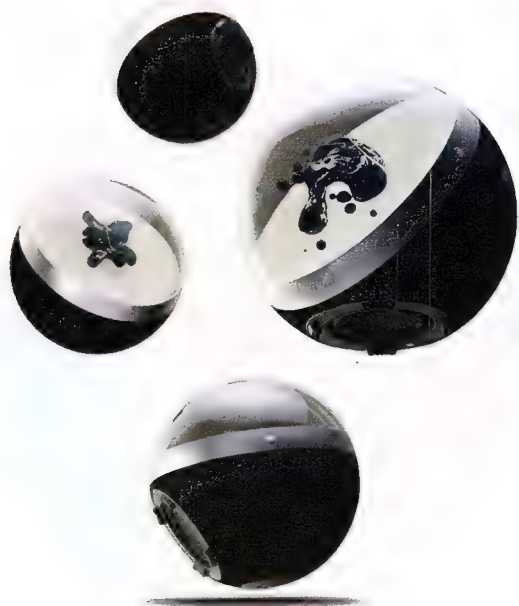


\$3,099 | astellinkern.com

ASTELL&KERN ACRO CA1000

If you have nice headphones...

If you're an audiophile, the chances are you're kitted out with some high-end headphones to ramp up your aural experience. But you can't get the most from your audio setup without a dedicated headphone amp and digital-to-analogue converter (DAC). But don't worry, because the new Astell&Kern ACRO CA1000 could be just the ticket. This combines a high-quality headphone amp with a premium DAC to make your music, podcasts and more as close to the original, intended output as possible (a goal boosted by native DSD512 high-resolution playback).



US\$399 | vanderwaals.tech

VAN DER WAALS

An intriguing centrepiece to any room in your house.

Music and movement have always been perfect partners, and the Van der Waals speaker combines them into a single, eye-catching product. The front of this unusual device is a large display area containing ferrofluid, which is essentially a set of magnetic particles suspended in a liquid. As your music plays, the vibrations move the ferrofluid into different patterns and shapes unique to each song. Around the back of the compact design is the device's speaker, which works with Bluetooth 5.1 and high-resolution codecs like aptX HD. And nestled behind the ferrofluid is an LED light with a diffuser – ideal for an ambient light show, day or night.



\$3,999 | xgimi.com

XGIMI AURA

Time to grab the popcorn.

A projector is a brilliant way to enjoy a big-screen experience in your own home. But the problem is that most require a lot of space due to their large throw distances. The XGIMI Aura, erm, throws all that out the window. Place it just 44cm from a surface and it can project a 150-inch picture. But it can go further than that: You'll get a 120-inch image from just 30cm away, or an 80-inch picture from a mere 11cm. That makes it perfect for compact spaces where you don't have a lot of room to work with.



\$9,399 | apple.com/au

Apple Mac Studio

Apple's got a new processor, a new creative workstation and a new pro display that take on the Mac Pro range for just a fraction of the price.

Apple has launched a series of M1 processors alongside different consumer products over the last couple of years, and each has dramatically changed our perceptions of what's possible from a laptop computer processor. The Mac Studio is the first time Apple has attempted to use its own processors in a creative workstation going head-to-head with the best consumer processors Intel and AMD make.

The new M1 Ultra processor used on some models of the Mac Studio is essentially two M1 Max processors fused together using a novel UltraFusion silicon interposer that allows enough low latency bandwidth for the chips to act as a single SoC. This system works so well that only one \$6K plus AMD workstation CPU – the Threadripper 3990X – just barely outperforms the M1 Ultra in popular CPU benchmarks. When you consider you can get an entire M1 Ultra Mac Studio, starting at \$6,099, it's a pretty amazing outcome.

The mighty M1

We took a deeper dive into the M1 Max for our MacBook Pro review in APC 501, and at the time this processor outperformed the best laptop processors we had on file from both AMD and Intel. Intel has since overtaken it with the mobile i9-12900HK, but the M1 Max processor is still good enough that Apple



	Apple Mac Studio	Alienware Aurora R13
Geekbench 5 - Multi-core (score)	33,900	17,225
Cinebench R23 - multi-threaded CPU	24,210	22,029
Power Supply (Max)	370W	750W
Geekbench 5 - Open CL (score)	87,345	205,783
Metro: Exodus - 1080p Ultra (fps Av.)	90+	135
Sid Meier's: Civilization VI (score)	46	37
CrystalDiskMark Read (MB/s)	6,225	6,404
CrystalDiskMark Write (MB/s)	5,480	4,380

Specifications

Mac OS 12.3; Apple M1 Ultra 20-core CPU, 64-core GPU, 32-core Neural Engine; 128GB Unified Memory; 2TB SSD Storage; 19.7 x 19.7 x 9.5cm; 3.6kg.

is releasing a variation of the Mac Studio that uses the M1 Max as its foundation. This starting configuration comes with a 24-core integrated GPU, 32GB of Unified Memory and 512GB of SSD storage for \$3,099 – some \$1,550 less than an equivalently specced MacBook Pro 14.

While this entry Mac Studio is competitively priced and will offer more than enough power for many creative workflows, if you are looking for a serious workstation, the M1 Ultra configuration is where the truly amazing performance is. Apple sent us one of the highest spec Mac Studios to benchmark, with an M1 Ultra CPU, 64-core GPU, 128GB SSD and a 2TB SSD that retails for \$9,399 locally. On both Cinebench R32 and Geekbench 5 multi-core benchmarks the M1 Ultra offered almost double the performance of the already impressive M1 Max.

If you compare the Mac Studio we tested to an \$8,436 Alienware Aurora R13 we tested at the end of 2021 – which included an Intel Core i9-12900KF CPU, 32GB of RAM and a Nvidia RTX 3090 GPU – then you see that the Mac Studio outperforms it by 38 percent on Geekbench 5 multi-core and by 9.9 percent on Cinebench R23 multi-core tests. This isn't overly surprising considering the Mac Studio is more expensive, it's got 16 high-performance



apcEDITOR'S
CHOICE

cores rather than just eight, and its 128GB memory allocation is almost incomparable to the R13's 32GB RAM allocation, but there's a bunch of ways you can skin this particular apple.

The most obvious is that the Mac Studio is a 20 by 20cm, 3.6kg compact desktop box rather than a 59cm tall 16.5kg gaming tower, and yet even when you really push the Mac Studio to its limits you can barely hear its fans engage, a feat that is only possible because of the significantly lower power draw from using Arm-based processors and advanced low-impedance thermal architecture. But then, if you follow Apple's marketing angle, the Mac Studio also only uses a fraction of the power of what this Aurora R13 does, which may add up to meaningful power savings over years of heavy use.

GPU performance

Apple has made some highly asterixed claims about GPU performance that have led to angry online rebukes outlining how the M1 Ultra is not more powerful than an RTX 3090. According to the benchmarks we use this is true – the M1 Ultra achieved less than half the score on Geekbench 5 (Open CL) compute benchmarks, and while some games like *Metro: Exodus* played at over 90fps on 1080p Ultra settings, which wasn't too far off 3090 performance, other titles did not do well at all.

While these are the ways we generally benchmark performance, it's perhaps an unfair comparison since the Mac Studio isn't designed, or pitched, as a gaming PC. The M1 Ultra GPU has 10,432 fewer cores than the 3090, but it can access up to 5.3 times the memory, so performance is going to vary considerably depending on the task. Apple is reporting meaningful gains on a wide range of software from Final Cut Pro to Houdini FX compared to earlier Macs, so while it might be inferior to leading gaming PCs when it comes to games, it should hold up really well for any work tasks.

The Mac Studio is compact, quiet and sleek looking. It's got more Thunderbolt ports than you have peripherals and enough other handy interface options to keep everyone happy. You'll have to factor in the cost of a display, keyboard and mouse or trackpad, but even adding those it's still a reasonably priced offering for a top-shelf workstation.

■
An amazingly powerful workstation in a uniquely compact form for a reasonable price.

Joel Burgess

★★★★★

\$3,599 | apple.com/au

Apple Mac Studio Display

The monitor bar lifts again.

Specifications

27-inch Retina display at 5120 by 2880 pixel resolution ; 600 nit brightness; full DCI-P3 colour; 12MP 122-degree ultra wide webcam with Centre Stage; 6 speaker Dolby Atmos; 1 x Thunderbolt, 3x USB-C ports; 62.3 x 48.7 x 16.8; 6.3kg.

The Studio Display is a 27-inch 5K Retina monitor from Apple that is designed to tick all the boxes many creatives need without being unnecessarily expensive. Starting at \$2,499, the Apple Studio Display is still definitely not cheap, but it's a very different ballpark to the \$10K Pro Display XDR that Apple offers.

The 5,120 x 2,880 resolution monitor has a pixel density of 218ppi, much higher than we're used to seeing, even on pro monitors. This hi-res picture is bolstered by a higher than usual 600nit brightness and full DCI-P3 colour space reproduction capabilities. When using the P3-600 nits preset the screen combines with either the included low reflectivity glass or, for an additional \$500, an even less reflective nano-texture glass to create an extremely vibrant display with minimal reflective distractions.

It's worth noting that this isn't a no-compromise professional monitor. When working in the full DCI-P3 or other professional colour presets, the overall brightness does drop significantly. It's still bright enough to work on, which isn't always the case on

less expensive pro colour monitors, but it's a different experience to the standard 600 nit preset.

The Studio Display comes with a 12MP Ultra Wide webcam that has a 122-degree field of view. This camera combines with the display's included A13 Bionic processor (from the iPhone 11 Pro) to digitally zoom and put you in the centre of the screen. It'll even zoom out to fit more people when it recognises they're there.

Backing this up is a six-speaker Dolby Atmos array that is good enough to mean you don't need any other speakers cluttering up your desk and there's plenty of ports to dock peripherals, plus a bunch of potential software features considering the inbuilt smartphone processor. While you can easily get away with the included tilt-adjustable stand, you'll have to fork out an extra \$500 for a stand that'll also do height adjustments.

■
A nicely balanced pro screen that's just a tad dark in colour accurate modes.

Joel Burgess

★★★★★

\$3,149 | microsoft.com/en-au

Microsoft Surface Laptop Studio

Microsoft is resurfacing its most powerful convertible with studio-quality perks that will appeal to anyone that gets creative with a stylus.

It's been a couple of years since Microsoft released the Surface Book 3, so it's about the right time for an update to this line. But in a minor surprise the Windows developer seems to have reinvented the branding of these powerful ultraportables and has renamed it the Microsoft Surface Laptop Studio.

Instead of offering a detachable tablet experience like the Surface Book, the Surface Laptop Studio has a screen that can fold into a drafting table shape to make it easy to draw on. The design (and title) is clearly borrowed from the company's desktop all-in-one, the Surface Studio, and is perfectly suited to be used with the recently updated Surface Slim Pen 2.

The laptop has a recessed edge that we originally thought was to make the powerful 1.9cm device look a little less bulky in photos, but this unusual shadow-line edge design actually creates an inverted shelf that can store the Slim Pen 2 and makes room for unimpeded thermal vents on either side.

The design makes sense for the purpose Microsoft intended, but it does reduce the area available to interface connections, so we understand why it hasn't been attempted before. Still, it fits a pair of Thunderbolt ports, the Surface Connect port, and a 3.5mm audio jack – just don't expect to see any USB Type-A ports here.

The 14.4-inch PixelSense display looks really impressive, even when sitting next to the Alienware Quantum Dot OLED reviewed on p38. Sure it's a little more glossy and doesn't have the



Specifications

W11 Home; 14.4-inch PixelSense Flow display at 2400 x 1600 pixel resolution; Intel Core i7-11370H CPU; Nvidia RTX 3050 Ti GPU; 16GB RAM; 512GB PCIe SSD; 57Wh battery (6h4min 1080p movie playback); 32.3 x 22.8 x 1.9cm; 1.8kg.

same depth in the blacks, but the 2,400 x 1,600 pixel touchscreen has a 1,500 to 1 contrast ratio and a vibrant 201 PPI pixel density. It only just scrapes in to achieve 100 percent sRGB colour reproduction though, so you can't really use it for colour grading work, even if it does look great.

Other than containing a hinge that allows the screen to fold into a hovering tablet or a-frame shape, the screen also contains the neat advantage of offering a 120Hz display that makes the already responsive Surface Slim Pen 2 seem even more silky, and opens up interesting gaming potential.

While the entry level Surface Laptop Studio comes with an Intel Core i5-11300H CPU and integrated Iris Xe Graphics, you can configure it with an

Intel Core i7-11370H CPU and an Nvidia GeForce RTX 3050Ti GPU for \$3,149. Both models come with 16GB of RAM and will be fine for a wide range of workloads, but the latter is going to have slightly more overhead for using design software. It's not bad at gaming either, with the i7 unit we tested racking up 49fps averages on games like *F1 2021* using Ultra 1080p settings.

Battery life isn't amazing at seven hours and four minutes of PCMark 10 Work benchmarks, and a little over six hours of movie playback, but it's not horrible for an ultraportable with a discrete GPU.

The keyboard and trackpad are nice and comfortable and it's got a custom set of 'Quad Omnisonic' Dolby Atmos speakers to elevate the spatial audio of any media playback.

You'll get a similar laptop experience from the Asus VivoBook Pro 15 OLED for \$2,299 if you don't mind a three hour battery life, but there's not really anywhere else you can get this kind of touchscreen and drawing interface.

	Microsoft Surface Laptop Studio	Asus Vivobook Pro 15 OLED
PCMark10 - Overall (score)	5,036	5,941
Cinebench R23 - CPU (multi-threaded)	5,036	5,941
3DMark Time Spy (score)	4,432	4,154
The Division 2 - 1080p, Ultra (fps)	43	41
Battery life - 1080p video playback (h:min)	06:04	02:55
Peak CPU temperature (°C)	91	96
CrystalDiskMark Read (MB/s)	3,517	3,456
CrystalDiskMark Write (MB/s)	2,979	2,894

A powerful convertible laptop with neat digital sketching perks that comes at a bit of a premium.

Joel Burgess

★★★★★

\$3,399 | rog.asus.com/au

Asus ROG Flow Z13

A tablet that will keep the games flowing, wherever you go.

There's quite a few devices and even plenty of software that merges the handheld, console and PC gaming arenas these days, but being able to game at your desk and then move into the living room or even to bed without stopping is a luxury that you still need to jump through a few hoops to do. The Flow Z13 is a Surface-Pro-like tablet that houses some impressive components to allow you to take your high-res PC gaming anywhere you want, out of the box.

While it might be a 13.4-inch tablet that's just 1.2cm thick 1.18kg, it's actually the first device we've seen with the absurdly powerful Intel Core i9-12900H CPU under the hood. This is backed up by 16GB of RAM, a Nvidia GeForce RTX 3050Ti and a 1TB SSD in a model that retails for \$3,399. You can save yourself \$300 by winding back those specs to a Core i7-12700H processor and an RTX 3050 GPU if you can live with a 512GB SSD on your gaming unit.

Alternatively, the Flow Z13 comes in an i5 variation that relies on the integrated Iris Xe Graphics to render games, an option that is undoubtedly more affordable at \$2,499 but that perhaps won't be ideal as a gaming device on its own. This Flow Z13 model is competitively priced against Microsoft's Surface Pro 8 range once



Specifications

W11 Home; 13.4-inch 120Hz display at 1920x1200 pixel resolution; Intel Core i9-12900H CPU; Nvidia GeForce RTX 3050 Ti; 16GB RAM; 1TB SSD; 56Wh Battery (6h9min 1080p movie playback); 30.2 x 20.4 x 1.2cm; 1.18kg.

you factor in SSD size and the included keyboard and it can even be a pretty decent gaming rig if you want to pair it with the ROG XG Mobile external GPU that Asus launched last year. The ROG XG Mobile adaptors aren't overly available locally, but we have seen some going with AMD RX6850M XT GPUs (pretty close to a Nvidia RT 3080 mobile) for \$1,699.

We tested the top tier Asus ROG Flow Z13 with a ROG XG Mobile CG31 containing a Nvidia RTX 3080. There's three GPUs in this configuration and three different levels of gaming performance depending on what's plugged in at any point. With the external graphics

you'll get 85fps+ on most titles using 1080p Ultra settings, but if you're hoping to get away with just using the tablet and its 3050 Ti, then you're looking at more the 40+fps range for Ultra 1080p or 60+fps using 1080p Low, when the unit is still plugged into power.

If you do want to run it off the battery you really shouldn't expect too much. Frame rates were capped at 30fps by default for all the titles we tested and battery life was just an hour and 15 minutes. You do get a bit more watching movies (six hours nine minutes) and doing work (four hours 23 minutes), but you won't ever want to be too far from power.

While the i9 processor means the work benchmarks are some of the highest we have on file, and the framerates are solid there are some caveats to the gaming experience. The first is that even though the display is 120Hz it has an unusually high 30ms response time. We didn't notice any lag when playing fast-paced online games, but it's high enough that it's going to be comparable to streaming to a regular tablet over something like Steam Link if you do have a PC capable of doing the brunt of the processing.

While it might be a 13.4-inch tablet that's just 1.2cm thick 1.18kg, it's actually the first device we've seen with the absurdly powerful Intel Core i9-12900H CPU under the hood.

	Asus ROG Flow Z13	Asus Vivobook Pro 15 OLED
PCMark10 - Overall (score)	5,837	5,941
Cinebench R23 - CPU (multi-threaded)	38,311	4,818
3DMark Time Spy (score)	4,447	4,154
F1 2021 - 1080p Ultra (fps)	61	73.6
Battery life - 1080p video playback (h:min)	6h9min	2h55min
Peak CPU temperature (°C)	93	96
CrystalDiskMark Read (MB/s)	3,355	3,456
CrystalDiskMark Write (MB/s)	3,231	2,894

A decent gaming tablet that solves a specific problem for a niche group.

Joel Burgess

★★★★☆



\$2,299 | dell.com

Alienware AW3423DW QD-OLED Gaming Monitor

Dell delivers the world's first Quantum Dot OLED gaming monitor and it might just be the perfect gaming screen.

Between the low latency response times and the lower overall brightness requirements of computer monitors, OLED displays are arguably the perfect technology for gaming displays. Yet, due to a combination of production costs and concern around the potential for burn-in, we haven't really seen many examples of OLED computer monitors to date.

The Alienware AW3423DW is the first gaming desktop monitor to market that uses a new 34-inch curved ultrawide OLED panel from Samsung. But if that wasn't noteworthy enough, this Samsung panel also integrates the company's proprietary Quantum Dot technology for the first time on any kind of display.

Samsung has announced it'll be releasing its own gaming monitor that'll use the same panel, but Alienware is leading the charge in bringing this curved high-res QD-OLED gaming display to market.

What's QD-OLED?

Quantum Dot LED (QLED) is a technology that Samsung has been pursuing since 2015 to avoid the brunt of investment costs associated with developing

Specifications

34.18-inch QD-OLED display at 3,440 x 1,440 pixel resolution; Nvidia G-Sync Ultimate; 175Hz refresh rate, 0.1ms GtG response time; 1,000nit peak brightness, 99.3% DCI-P3, 149% sRGB; HDR400; 81.5 x 30.5 x 52.5cm; 6.92kg (without stand).

expensive TV-sized OLED panels. QLED, is much better than general LCD panels at generating brightness, since instead of producing a white light and then filtering out energy to get the colour, it uses small dots of a material that absorbs the full amount of energy from a blue coloured light and transforms it, almost entirely, into another colour that is radiated directly.

This tech has allowed Samsung to achieve double the peak brightness of other LED-based TVs on the market and has been able to create enough contrast to, arguably, compete with OLED's overall. Interestingly, these two technologies actually compliment each other and are well suited to be used in conjunction.

While most LED displays use backlights to create brightness in areas and LEDs for adding colour, in OLED displays the brightness and colour come from the same light source. This means that while it allows the screen to produce much darker

zones, it also makes it much harder to get the same levels of brightness as an LED screen.

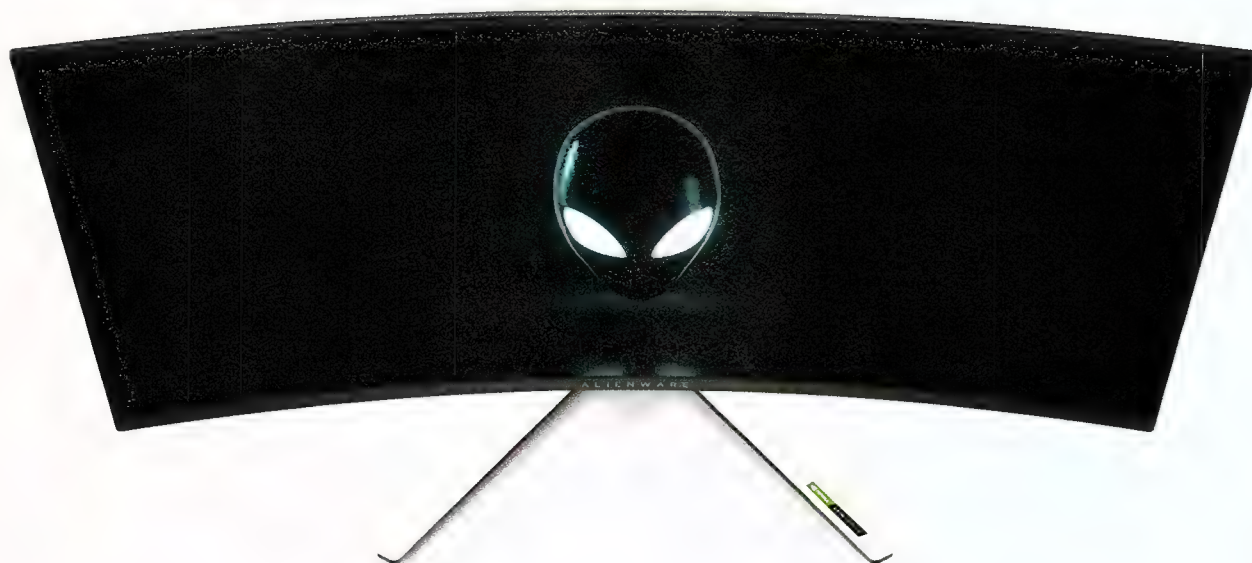
When used together the contrast range and image quality is quite extraordinary and makes the Alienware AW3423DW unlike any other display we've seen before. The blacks are deeper than any desktop monitor we've looked at and the brightness is also higher than what you can get on many other top-shelf gaming monitors.

G-Sync Ultimate

This makes it the perfect unit to showcase Nvidia's new G-Sync Ultimate certification, which allows you to run G-Sync in HDR modes at high frame rates. Although AMD beat Nvidia to high refresh rate, screen-tear free, HDR gaming with FreeSync Premium Pro last year, now anyone with an Nvidia GPU and a G-Sync Ultimate-certified display can run Nvidia's screen tearing tech with variable overdrive in 10- or 12-bit colour at up to 300fps (depending on the resolution).

It's one thing to be able to carry HDR content, but screens will vary dramatically in terms of how well they can reproduce those colours and the AW3423DW is as

The Alienware AW3423DW is the first gaming desktop monitor to market that uses a new 34-inch curved ultrawide OLED panel from Samsung.



OLED is known to be a responsive screen technology, so it's not that surprising that the Alienware AW3423DW offers high refresh rates, but its native 175Hz is pretty amazing when you consider everything else on offer here.

good as gaming displays get. First it's able to reproduce 99.3 percent of the DCI-P3 colour gamut and offers a colour accuracy of Delta E<2, which is right on the cusp of professional level colour grading capabilities. Combine this with the monitor's unusually high 1000nit peak brightness and the deep contrast of the OLED panel and you get game colours that are as accurate and as impressive as they can be.

While these colour specs make it the perfect monitor for immersing yourself into a nice long RPG, the display is also equipped with some pretty impressive refresh rates for when you want to get competitive in online shooters. OLED is known to be a responsive screen technology, so it's not that surprising that the Alienware AW3423DW offers high

refresh rates, but its native 175Hz is pretty amazing when you consider everything else on offer here.

This is complemented by what Samsung and Alienware claim is the 'industry's fastest' 0.1ms GtG response time. So there's really no sacrifices here and as long as your internet and other components are up to speed, this screen won't stop you from professional-level competitive gaming.

Ahead of the curve?

The 34-inch curved QD-OLED has an 1800R curvature, which means its curve follows the same arc as a circle with a 1.8m radius. This is the most common curve you'll see in ultrawide desktop monitors these days, so it makes sense to run these expensive panels in this form

factor. Samsung's 49-inch Odyssey Neo G9 gaming monitor uses a more extreme 1000R curve that wraps way further around into your peripheral vision and is perhaps the only other monitor we've tested that competes with the Alienware AW3423DW in overall immersion.

Alienware has done a great job with designing the rear chassis and monitor stand, which continues the white aesthetic you see on its Aurora desktops and X gaming laptops. There's also a couple of USB Type-A ports and a headphone jack on the bottom of the screen for easy access, which is handy since a lip on the bottom rear of the monitor makes it a little fiddly to connect the power and interface options.

The only connectivity option we're really missing here is a USB-C/Thunderbolt connection since it's got a DisplayPort (1.4) and two HDMI (2.0), but the most likely use cases are covered so this isn't critical for most.

The joystick at the bottom of the display is also easy to use and the menu interface offers a reasonable selection of presets and all the other menu options you could want. The picture quality is good on all the presets we looked at, but we did tweak the creator mode to be a little brighter (which will affect colour accuracy, but not by too much).



It's not cheap, but QD-OLED is the new benchmark in gaming display tech and it's already on a curved ultrawide. An amazing, no-compromise gaming display.

Joel Burgess

★★★★★



\$479 | benq.com/en-au

BenQ GW2785TC

A 27-inch work monitor that's designed to be easy on the eyes.

We'd all love the latest \$2,000 ultrawide monitor, but for many this just simply isn't an affordable option for a monitor you primarily use for work tasks. And that's exactly who BenQ's GW2785TC is built for, someone looking for an entry-level work monitor that allows you to look at spreadsheets and web pages till you crack that bonus threshold.

The BenQ 27-inch Full HD GW2785TC isn't the cheapest monitor out there, instead it's attempting to coax buyers over the line with a raft of eye saving features that should appeal to people who spend the whole work day at their screen.

The validity of these eye saving features will vary depending on who you ask, but there's plenty of science backing up the impact of blue light on your circadian rhythm, and BenQ has gone to the effort of getting independent TÜV Rheinland Certification for its Low Blue Light and Flicker Free tech.

For anyone that works late and has trouble sleeping the eye saving features

Specifications

27-inch IPS display at 1,920 x 1,080 pixel resolution; 250nits typical brightness; 1,000 to 1 contrast; 5ms (GtG response time); 99 percent sRGB colour; noise cancelling mic; 2 x 2W stereo speakers; 45 degree swivel, -5 to 20 degree tilt; 61.2 x 53.5 x 23.4; 7.8kg.

might be a worthy investment, but if you clock off at five or you already use apps to redshift your display, it probably won't make much of a difference. There's also a more novel eReader setting that turns the display into a low-energy Kindle-like display that should appeal to anyone who digs into longer-form reading on their PC later at night.

The BenQ GW2785TC uses a stock 27-inch flatscreen format with a FullHD pixel array, which is just dense enough on a screen of this size to not look overly pixelated when looking at documents or images. The screen is big enough to comfortably look at a couple of documents or web pages side by side or watch video content in a standard 16:9 wide video format.

The display isn't overly bright, but it's enough to not be a problem at maximum brightness. The menu is more comprehensive than what you'll get on

really budget displays and the interface options are reasonable. It's also got a handy inbuilt mic with noise cancellation, a hardware switch and a status light, as well as a pair of 2W speakers, which will pair nicely with a standalone webcam for any online meetings.

The GW2785TC's USB-C, HDMI 1.4 and DP 1.2 inputs are enough to keep power-users happy. This arrangement allows you to run 60W of power back to your laptop using the USB-C connection or use the additional DisplayPort-out to daisy chain a second monitor from your laptop.

Price is going to be one of the most important factors on the table for anyone in the market for a standard work monitor. The BenQ GW2785TC is definitely not the cheapest 1080p 27-incher out there, but at \$479 (or even \$409 on sale) it's not an entirely unreasonable asking price either.

The BenQ 27-inch Full HD GW2785TC isn't the cheapest monitor out there, instead it's attempting to coax buyers over the line with a raft of eye saving features that should appeal to people who spend the whole work day at their screen.

A solid 1080p work monitor with mic and speakers for anyone wanting something a little easier on the eyes.

Joel Burgess

★★★★☆

\$669 (13.3in), \$749 (15.6in) | espres.so

Espresso Display Version 2

Our favourite portable display gets an interesting update.

The new Espresso Display 2 is an iterative improvement on the first model, which launched in mid-2021 via a healthy \$307,000 Kickstarter campaign. The Version 2 model is a little thinner (5.3mm vs 5.5mm), but is otherwise similar in appearance to its predecessor. The important improvements are internal, with upgraded hardware that's designed to deliver better pen and touch compatibility.

This improved touch support is intended to benefit Mac users mostly and addresses a key weakness of macOS overall – in a unique and proprietary way. The original V1 Espresso Display operates in mouse emulation mode for touch and pen when connected to a Mac, but with the new V2 internals, and – crucially – an updated version of Espresso's espressoFlow software, Mac users can potentially use the display in native touch or pen mode.

While this sounds great for Mac users, it's important to note that pen and touch functionality within actual Mac apps needs custom support from each app's publisher. Espresso told APC that it's working with developers to achieve that, but it will be a progressive rollout staged over time, with the most popular apps supported first – assuming the various app publishers are on board and choose to implement support.

We connected the Display 2 to a Surface Laptop 4 and all touch and pen features worked flawlessly. Adding the display was a near-instant and flawless



Specifications

Resolution: 1920 x 1080; Brightness: 300 nits; Refresh rate: 60Hz; Connectivity: USB-C; Dimensions: 358 x 256 x 5.3mm; Weight: 865g.

experience. Once the USB-C cable was plugged in it detected the second screen immediately and was up and running without any further setup needed. The espressoFlow app can then be used to configure it in extend or mirror mode. Alternatively, you can also use Windows setup to achieve the same.

The look of the V2 is unchanged from the V1, and we're happy with that. Espresso's designers have made both versions exceptionally thin and light, with the lovely bevelled edges accentuating the aluminium body nicely. Appearance aside, the metal chassis is key to the portability of this device, and its durability.

A pair of USB-C ports on the side provide data and power (the second port

can be used for device charging), and small speaker holes in the rear provide audio – though in our testing they're useful for system sounds or voice only, and not so much for media enjoyment.

Espresso is pitching the Display V2 as ideal for creatives, and the panel has a claimed 99 percent sRGB coverage as well as being 10-bit, which is a welcome gain over the more common 8-bit LCD panels we usually see. Brightness is a passable 300 nits, and during testing we set a full-screen black background and there was no perceivable light bleed from any edges, or inconsistent areas across the display area during general use.

Power consumption is a miserly 5-7w, and it's fed via the USB-C cable – so no power brick required.

The Espresso Display 2 gets everything a good portable screen needs right. It's a dream for moving around without hassle and would ever so easily slip into a backpack alongside your laptop without adding any noticeable weight or bulk. It's also nice as a permanent desktop second screen, but the pricing means you're looking at a premium of at least \$200 compared to a similarly-specced regular desktop monitor.



Still the nicest portable display to use and move, now with an electronics and software update that promises native pen and touch support in MacOS.

Ben Mansill

★★★★☆

\$275 | www.asrock.com

Asrock B660 Steel Legend

If the idea of \$500+ motherboards makes you ill, have a look here.

It's a tough time for the whole world right now, for many well-known reasons. Here in Australia, inflation and supply chain issues mean that a good value-for-money motherboard is relatively hard to find. At \$275 the Asrock B660 Steel Legend is a board that tries to find the right blend of offering a decent feature set and value for money without looking like it's cheap. Is it a board that you should consider?

Some cheaper B660 boards really look cheap. The Asrock doesn't give that impression. It's got a VRM and cooling that can happily handle a 12900K, and – like all B660 boards – it has memory OC support, so straight away you have a board that can run a mid-range to high end system. Many people don't even need Z690.

The B660 Steel Legend features a military silk screendesign with white and grey heatsinks. It's got some very bright RGB lighting. One of the highlights is a PCIe 5.0 slot, which is omitted on many B660 boards. There are three M.2 slots, though only the primary slot has a heatsink. The middle one runs at PCIe 3.0 x2 speed. There are two PCIe 1x slots, which immediately puts it ahead of many mATX boards in its price range thanks to the ability to add multiple expansion cards.

It's easy to forget that we're talking about a cheaper board, but these days it's hard to get past the omission of Wi-Fi, especially as the Steel Legend goes halfway by including an M.2 e-key slot for a Wi-Fi card. You'll also



Specifications

Asrock B660 Steel Legend; LGA1700 Socket; 3x M.2; 6x SATA; Up to 1x USB 3.2 Gen 2x2, 1x USB 3.2 Gen 2, 6x USB 3.1 Gen 1, 4x USB 2.0; Realtek RTL8125BG 2.5G LAN; Realtek ALC897 7.1 Channel HD Audio; ATX Form Factor.

have to put up with Realtek ALC897 audio. Note that the board features a USB 3.2 Gen 2x2 front panel header, which is nice to see in this price range.

The VRM of the B660 Steel Legend is on the basic side, but since B660 cannot overclock, it's not expected to be as powerful a VRM as you'd find on a \$500+ Z690 board. The DrMOS VRM with nine 50A phases is easily able to power a 12900K.

The rear I/O comes with a typical set of ports in this price range. There's one Type-C USB 3.2 10Gb/s port, four 3.2 5Gb/s ports and two USB 2.0 ports. You get DP1.4 and HDMI 2.1 ports for use with Intel's Xe graphics, a PS/2 keyboard/mouse connector and a BIOS flashback

button. There's a single 2.5G ethernet port, which is controlled by a Realtek RTL8125BG chip.

The performance of the board was generally good. The Steel Legend doesn't have any problems when used with a 12600K, and with an unlikely pairing of an RTX 3080 Ti, the board performs on par with a Z690 DDR4 board.

The Asrock B660 Steel Legend is a fairly unremarkable board, but at this price, it's important not to expect too much. If you want an overclocking capable VRM or Wi-Fi 6E, you have to pay twice the price or a lot more. This is a board for those looking to build a mainstream system. Chuck in something like an i5 and a set of 3200MHz DDR4 memory and you've got the core of a no fuss system. Sure, it's unremarkable, perhaps even average, but if you're struggling to afford a decent GPU, save yourself a couple of hundred by buying a board like this. You'll get improved performance, leaving your motherboard out of sight and mind.

	MSI MAG B660 Tomahawk DDR4	Gigabyte Z690 Aorus Pro DDR4
Ghost Recon: Breakpoint - 1080p, Low, Avg FPS	225	224
Middle Earth: Shadow Of War - 1080p, Lowest Preset, Avg FPS	309	306
3DMark TimeSpy Extreme - Score	9,255	9,246
Cinebench R23 - Multi thread Score	17,454	17,467
Blender 2.92 Classroom - Time (seconds) Lower is better	398	396
7Zip - Million Instruction per second	86.67	86.21
Handbrake 1.4.2 - Video conversion 4K to 1080p FPS	64.1	64.1
CrystalDiskMark Write (MB/s)	2,979	2,894

The B660 Steel Legend does what it says on the box with no fuss, and that's all we expect of it.

Chris Szewczyk

★★★★☆

\$199 | www.westerndigital.com

Western Digital Black SN770 1TB M.2 NVMe SSD



PCIe 4.0 performance at PCIe 3.0 prices.

Ever since PCIe 4.0 drives were released, they've tended to occupy the upper end of the market, leaving PCIe 3.0 drives to fill the entry and mid-range SSD markets. That's all changing now. PCIe 3.0 drives are set to gradually disappear. As PCIe 5.0 drives are set to make their introduction later this year, affordable PCIe 4.0 drives like the Western Digital SN770 set a new baseline performance expectation that promises to elevate what you can expect from a mainstream NVMe SSD.

The 1TB SN770 we have in for review costs \$199. That's not much more than popular PCIe 3.0 drives, yet much less than the higher performing drives like the 980 Pro and Seagate 530. The WD SN770 is available in 250GB, 500GB and 2TB capacities. There's no 4TB option, but that may well come in the future.

In terms of specifications, the WD SN770 is a standard form factor 2280 (80mm length) M.2 drive. It makes use of Kioxia 112-Layer BiCS5 TLC NAND. WD doesn't disclose a lot about the controller apart from the fact that it's an in-house design, unlike many competing drives that use Phison controllers. WD is able to fully customise its SSD designs thanks to its integrated design and manufacturing capabilities.

Somewhat surprisingly, the SN770 lacks a DRAM buffer. Normally that would indicate it's not a high-performance drive, yet the SN770 comes with some excellent performance specifications. WD is certainly doing



The 1TB version is rated for 5,150/4,900 MB/s sequential read and write speeds and 740K/800K read/write IOPS. The 1TB drive features a 600TBW endurance rating. For a drive at this price, those are outstanding specs.

Specifications

PCIe 4.0 x4; Kioxia BiCS5 112L TLC NAND; 5150 MB/s sustained read, 4900 MB/s sustained write, 740K/800K read/write IOPS; 600 TBW endurance; Five year warranty.

something under the hood to deliver high performance while omitting a DRAM buffer. The 1TB version is rated for 5,150/4,900MB/s sequential read and write speeds and 740K/800K read/write IOPS. The 1TB drive features a 600TBW endurance rating. For a drive at this price, those are outstanding specs. It does lack hardware encryption support though.

The SN770 may not sit atop the sequential transfer speed tables, but its random read performance is outstanding, all but matching the very best NVMe drives. It's that measure that we look for in a consumer-level drive where write performance isn't as important. It will fall behind the best

drives at write operations, but unless you're transferring tens of gigabytes around, you'll hardly notice.

PCIe 4.0 drives can get a bit hot, but the WD SN770 delivered a peak operating temperature of 62C. You should get a lower temperature if you install it under a motherboard heatsink. You can use WD's simple Dashboard software to monitor temperatures and various other parameters.

It seems like most SSDs that we've reviewed over the last year have scored well. They've offered either outstanding performance or value for money. The WD SN770 absolutely offers both. It is priced at a point that leaves PCIe 3.0 drives all but obsolete for anything other than budget systems or bulk storage. As a consumer level drive, the read performance of the SN770 at low queue depth matches the best PCIe 4.0 drives. Its write performance and outright sequential performance is a bit behind, but it's the random read performance that really makes a drive feel fast.

At \$199 for the 1TB option, it's priced as a mainstream drive while delivering performance that's close enough to the best drives on the market. It's easy to recommend.

The SN770 offers outstanding value for money and read performance that's up with the very best.

Chris Szewczyk
★★★★★

			Western Digital Black SN850 1TB	Kingston KC3000 2TB	Western Digital Black SN770 1TB
CrystalDisk Mark	Sequential Read MB/s		7,071	7,386	5,225
	Sequential Write MB/s		5,229	6,891	4,971
Anvil Storage Utilities	4K Random Read MB/s	Queue Depth 1	82.4	83.1	82.7
		Queue Depth 4	300.2	328.7	278.8
	4K Random Write MB/s	Queue Depth 1	255.2	274.8	216.7
		Queue Depth 4	879.4	993.7	822.1
	4K Random Read IOPS	Queue Depth 1	21,099	21,266	21,184
		Queue Depth 4	76,855	84,146	71,369
	4K Random Write IOPS	Queue Depth 1	65,322	70,341	55,485
		Queue Depth 4	225,135	254,375	210,472
Internal File Copy	30GB of mixed file sizes	Time (seconds)	27		30



\$246 | www.dahuasecurity.com

Dahua PFM350-900 UPS

High on power, low on price.

Anyone that's used a PC for any length of time has surely experienced an unexpected power interruption. An uninterruptible power supply is one of those devices that tends to be underappreciated. It's stating the obvious, but you only need it when you need it. These days, particularly if you work from home, you don't want to lose valuable data. Alternatively, if you have a security system, the need for uninterrupted internet or you need to keep your phone charged in case of an emergency, a UPS can be very valuable.

Here for review we have a UPS from one of the lesser known names in the industry. The Dahua PFM350-900 is a 1500VA/900W line interactive UPS. It packs a lot of power into a simple unit that omits flashy extras with the aim of keeping the price low. Does it stack up against the big names in the UPS market?

The Dahua PFM350-900 is best described as a no-frills unit that's best suited as a simple battery backup for high powered devices including a powerful PC, even a gaming one. Its 1500VA/900W rating provides plenty of backup power to allow you to save and exit your game and

Specifications

Dahua DH-PFM350-900 Line Interactive UPS; 1500VA/900W Capacity; four Outlets; Overload, discharge and overcharge protection; Recharge Time: 4 hours to 90% capacity; Weight: 10.4KG

shut down, even while the GPU is gulping power. It comes with four AC outputs. We feel that its high-power output is a little wasted on a unit with just four.

To keep the cost down, the PFM350-900 omits things like an LCD readout or USB ports for device charging. You can forget about things like ethernet surge protection or much of anything else. The battery is not user-replaceable and it comes with a two-year warranty. It is a line interactive unit that features boost and buck automatic voltage regulation. The four outlets support overload, as well as discharge and overcharge protection, but first and foremost its purpose is a battery backup with little in the way of frills. On the plus side, the unit is very solid, though its plastic finish isn't up to the look and feel of more expensive units.

The PFM350-900 comes with a simulated sine wave battery output. Simulated sine wave outputs are perfectly acceptable for home use cases but for mission-critical equipment, a pure sine

wave unit is optimal. A simulated sine wave design is easier to implement, and that's a major factor in the affordability of the Dahua.

Our test with the unit involved powering a typical office PC with integrated graphics and a 4K monitor with the sleep functions disabled. The system was pulling around 80 to 100W, which meant the Dahua was able to run for over 80 minutes. Even with a 500W load, the unit should last for up to 10 minutes, which is plenty of time to save your work and shut down.

Would we recommend the Dahua over a well-known brand such as CyberPower or APC? It depends on your needs. If you're after a simple battery backup to prevent power loss in the event of a blackout, it will do the job well. But spending a bit more gets you a lot of extra features that leave the Dahua looking a bit plain when compared to the more well-known competitors.

The Dahua PFM350-900 is well suited to a high-powered rig but its lack of features and outputs count against it in the face of tough competition.

Chris Szewczyk

★★★★☆

The Dahua PFM350-900 is best described as a no-frills unit that's best suited as a simple battery backup for high powered devices including a powerful PC, even a gaming one.



\$349 | steelseries.com

SteelSeries Arctis 7+ Wireless Headset

Another impressive Arctis headset?

While there's no doubt SteelSeries has nailed its gaming headset designs, the ever-expanding nature of its range can be confusing. Take this 7+ model – it's an upgrade on the standard 7, but below the more premium 9-series, which also has a Pro version.

On the design front, it's no surprise this is a comfortable pair of headphones. SteelSeries' ski-goggle headband is one of the best on the market, suspending the headset from a steel band and creating an even pressure across your head thanks to the elasticated headband. This makes the headphones feel lightweight while still being durable. The rest of the construction is strong, with soft-touch black plastic feeling pleasant to hold, with no sharp edges in sight. The earcups are cozy around the ears, with plenty of cushioning to spread any potential pressure evenly. The result is that the 7+ provides cloud-like comfort, and maintains SteelSeries' reputation for the best gaming headsets on the market.

But what about functionality? On the right earcup, there's a power button that also functions as a multimedia button for picking up calls, playing music, pausing,

Specifications

Driver Type: 40mm Neodymium driver; Frequency Response: 20Hz-20,000Hz; Impedance: 32ohms; Connectivity: Analog, 2.4 GHz lossless, USB-C; Compatibility: PC, Mac, PS4, PS5, Nintendo Switch, Android; Battery life: 30+ hours; Design Style: Closed-back.

and skipping tracks. It also has an LED indicator that shows the power left in the battery, running from green down to red. Above the power button, you also get a wheel for balancing between game or voice chat which is perfect for adjusting the audio mix on the fly. On the left can, there's a mic mute button, a smooth volume wheel, a port for a four-pole 3.5mm audio cable, and a headphone share jack to allow friends to join in the music – a rarity on most gaming headsets. Finally, there's a retractable microphone, which boasts great clarity and pick-up so you're always clear when talking to your squad in party chat.

The Arctis 7+ comes with an odd-looking USB-C wireless dongle, but it has a wide range of compatibility. You can use this headset on PC, Mac, PlayStation 4/5, Nintendo Switch, Android (if it has USB-C connectivity), and any 3.5mm device. Although these headphones have analog, USB, and wireless connectivity, they don't

have Bluetooth, unlike its pricier sibling, the Arctis 9 Wireless.

Sound quality from the 7+ is what you'd expect from SteelSeries. Out of the box, the naturally flowing soundscape focuses on the high-end, providing you with plenty of clarity and detail which sounds great in most games. Using the SteelSeries GG engine and its Sonar tool, you can tweak the sound to suit your taste. Increasing the bass gave the headphones a fuller and richer sound, which ticks all the boxes, sonically.

If you're looking for a reliable, comfortable headset that provides versatile compatibility then you won't be disappointed with the Arctis 7+. It's an updated version of a solid device and features some modern touches that its predecessor lacked. SteelSeries has nailed the formula and has produced another well-rounded pair of headphones with a detailed soundstage. If Bluetooth is a must, then you should try the Arctis 9 Wireless. If not, the Arctis 7+ does everything you need.

Out of the box, the naturally flowing soundscape focuses on the high-end, providing you with plenty of clarity and detail which sounds great in most games.

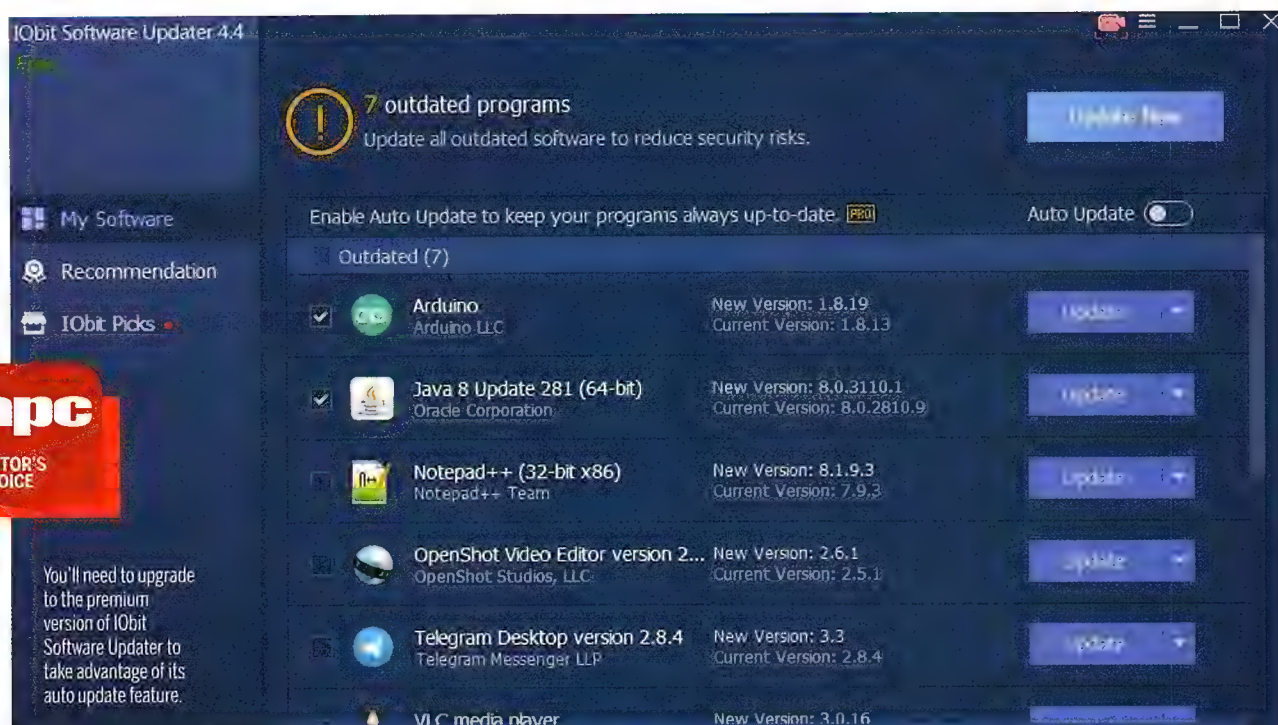
■
Pillow-like comfort with a clear microphone and well rounded sound, though no Bluetooth.

Sam Lewis

★★★★☆

SOFTWARE

APPS FOR ALL YOUR PLATFORMS



WINDOWS APPS | US\$13 per year | iobit.com

IObit Software Updater

Effortlessly update the software installed on your PC to the latest version.

IObit Software Updater is a device optimisation tool developed by the American software company IObit which is a recognised industry leader in optimisation and security software tools. It produces many other types of software apart from Software Updater, including a VPN, a software uninstaller, and an antivirus.

IObit released the first version of Software Updater in 2018 and has dropped consecutive updated versions yearly. It released the latest (fourth) version in January 2022, which we'll review based on specific criteria, including features, compatibility, customer support, ease of use, etc.

There's a free version of the IObit Software Updater that anyone can download. It has the basic software updating features but lacks compared to the premium version. You need to pay for the premium version to unlock access to all the functionalities we'll show you. The premium version is available through an annual subscription. It costs US\$13 to buy a yearly license covering three PCs. It's

readily available on IObit's official website, and you can pay through PayPal or with a debit or credit card.

Like other IObit products, Software Updater includes a number of tools and features to ensure the software on your PC is up to date and optimised. The Software Scans and Updates feature is the primary essence of the IObit Software Updater. You can scan your computer at any time to check for which software programs are outdated. It highlights all the outdated software and lets you update them right away.

In our test on an HP laptop running Windows 10 Pro OS, the tool found seven outdated programs, which we immediately took care of. After it scans and reports back which software programs are not up-to-date, IObit Software Updater lets you update all the outdated programs in one click.

You can also set IObit Software Updater to automatically update any outdated software on your computer without your explicit consent.

IObit Software Updater can check for

vulnerabilities in any software you have installed. This feature is not an essential functionality but a plus. IObit Software Updater has a recommendation toolbar to find and install software programs for specific purposes. There are recommendations for browsers, security software, multimedia software, remote work software and more.

IObit Software Updater is user-friendly. It's a simple app without many functions, so you can always find whichever one you need. However, we noticed one drawback: IObit tries hard to advertise its other software products on the Software Updater. These advertisements can be intrusive, especially for free users.

After using IObit Software Updater, we concluded that it's a good utility tool for every PC. It has certain drawbacks, but it's often the cheapest option among competitors and a good deal relative to the features you get.

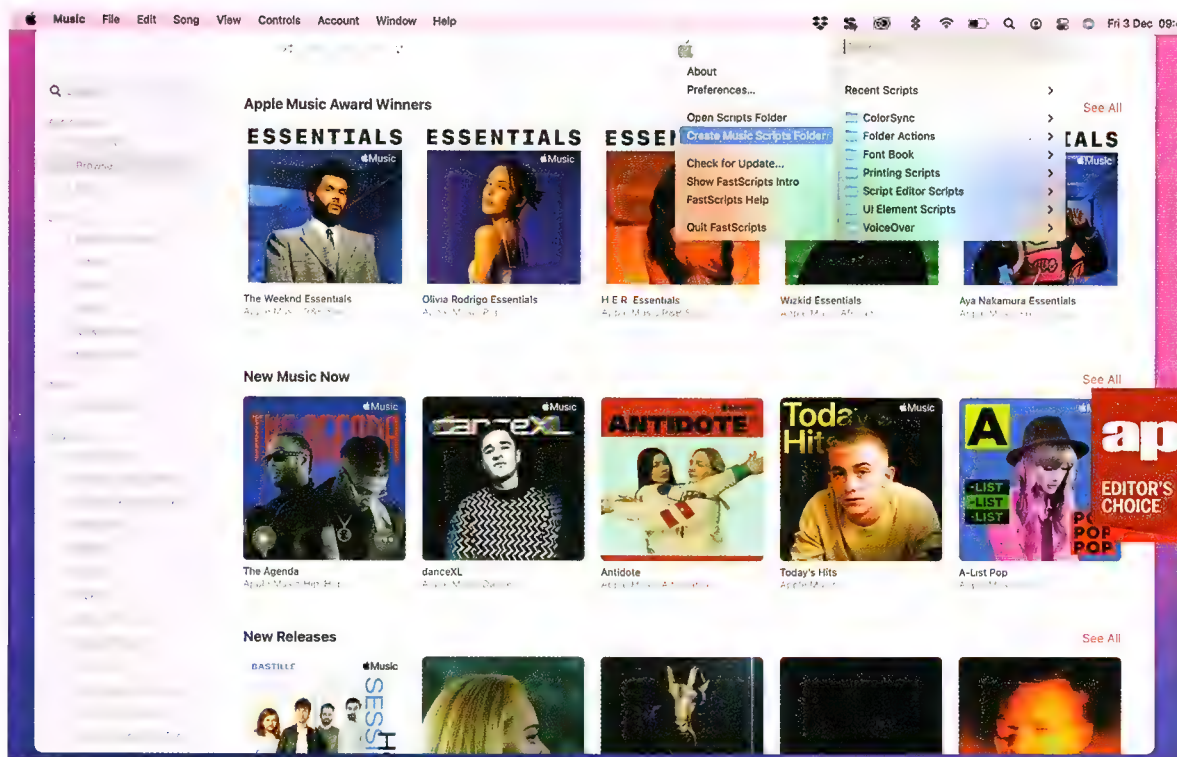
You can try the free version first to get familiar with the software and upgrade to the paid one if you're satisfied with it.

There's a free version of the IObit Software Updater that anyone can download. It has the basic software updating features but lacks compared to the premium version. You need to pay for the premium version to unlock access to all the functionalities we'll show you.

Relatively cheap with a free version available, automatic scans and updates, user-friendly software that's quick to download and install.

Stefan Ionescu

★★★★★



FastScripts 3 can create an app-specific Scripts folder for the active application.

MAC STORE & OTHER MAC APPS | Free/US\$39.95 for premium | redsweater.com

FastScripts 3.0.3

Quickly find, execute, or edit scripts using this handy menu bar utility.

If you've ever done more than dabble with AppleScripts, or any other scripting on the Mac, you'll know that macOS' Script Editor gives the option to put a Scripts menu in your menu bar. That menu gives you access to scripts in the default Scripts folder, so you can view and edit them easily. FastScripts also does that and a whole lot more. Version 3 has been updated with a host of new features and makes it even more of a 'must-have' for anyone who uses AppleScripts on a regular basis.

There's a new search box at the top of the menu, enabling you to use Spotlight to search for scripts. Click the menu, start typing (there's no need to place the cursor in the bar) and FastScripts will filter the list of scripts.

You can now execute multiple scripts in parallel – scripts run independently of the app to which they belong, allowing multiple scripts to run simultaneously without affecting the performance of the app or other scripts. FastScripts also now supports Apple's standard reporting mechanism for AppleScript, meaning that for suitable scripts, FastScripts will display their progress in the menu, display text feedback, and enable you to stop scripts.

FastScripts has several other features to make working with scripts simpler and, well, faster. If you option-click a script, it will open in Script Editor, or another script editor if you prefer. Up arrow-click a script and it will be revealed in Finder, and if you command-click one, FastScripts will take you directly to the place in its Preferences where you can specify a keyboard shortcut to open it directly.

There's also a command that enables you to create a scripts folder for whichever app is active on your Mac at the time – though you will need to use the menu command to create a Scripts folder in your user library first, if there isn't one already. However, it's still much easier than

having to create a Scripts folder manually. And FastScripts, unlike macOS' Scripts menu, can be used with Shell scripts as well as AppleScripts.

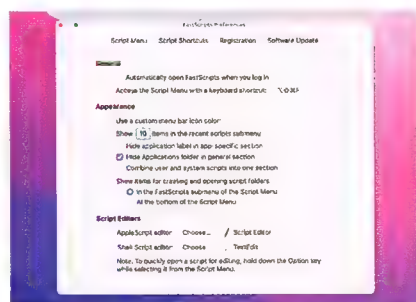
All of these features – with the exception of keyboard shortcuts – are available to use without restriction in the free version. When you use keyboard shortcuts in the free version you will see a reminder that keyboard shortcuts are a premium feature, but they will still run. That reminder will also appear when you use built-in scripting additions such as the 'display message' and 'open web page' commands. However, the commands will still run.

We think FastScripts is terrific. For anyone that spends time on their Mac working with, or even just executing scripts, it's well worth a place in your menu bar. If you're an avid user of AppleScripts, you'll want to install FastScripts to reap the benefits of its version 3.

FastScripts is an essential app for anyone who either writes or edits scripts frequently.

Kenny Hemphill

★★★★★



If you don't want to use Script Editor to edit scripts, you can change the app that opens when you option-click.

Free | iOS/Android

Brave Browser

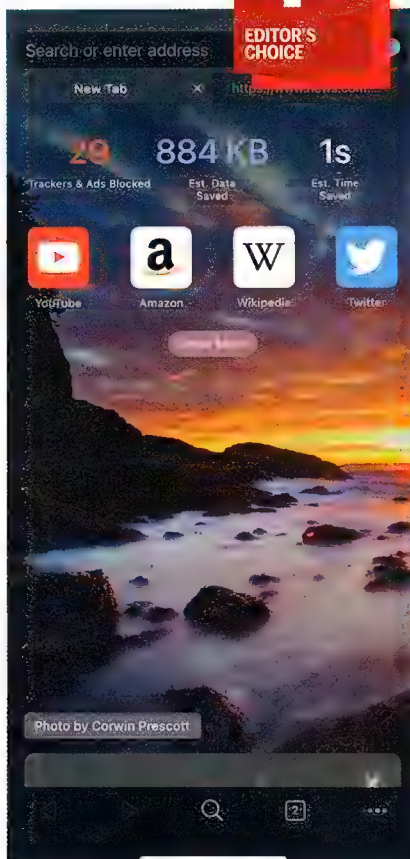
Security focused.

While most browsers now make privacy a pillar of their development, Brave has always had an intense focus on making it the absolute core of its foundation. Literally every part of the experience is related to making sure it knows as little about you as possible, and the open web even less so.

Brave looks and feels like everything else – it has a tab system, it has bookmarks, it has a dark mode. It matches all the major features of competition like Edge, Chrome, and Safari. But where the benefits lie are in many of the built-in features that tend to be extensions – like a free ad blocker, script, cookie and strict tracker blocker, and HTTPS everywhere support.

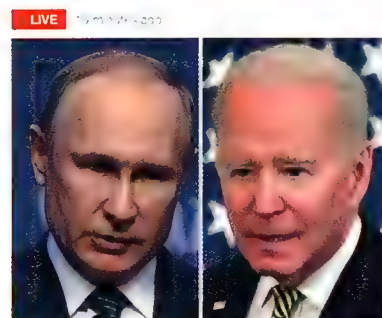
Brave also offers its own search engine and rewards system, which works on a crypto token that it pays out when you view ads from search or on the home screen. This function varies however – during my testing it was in and out of a beta on iOS but seemed to be solid on Android. I did appreciate the shared revenue feature however, especially when you'd always normally pay to surf via watching ads.

The other benefit to cutting out the large bulk of cruft that infests the corners of the modern web is that Brave is insanely fast. I compared it to both



Safari and Chrome and in its default state without any extra extensions and it was at least twice as fast loading pages, especially news sites, which tend to have a lot of ads and trackers.

On the flipside, Brave's attempt to cut the crusts off also means some websites just flat out don't work at all. Thankfully this is rare, but I did notice in some



'UNACCEPTABLE AND UNFORGIVABLE': Fury over Biden's Putin sledge

Joe Biden's decision to brand Vladimir Putin a "war criminal" has enraged the Kremlin, with a spokesperson blasting the "unforgivable" comment. Follow our live updates.



cases I had to muck around with some of the settings to fix a number of pages that refused to load properly. It's also a little difficult to white-label some sites you would like to support as the default option is quite strict.

★★★★★
James Pinnell

Free with IAP | iOS/Android

PETTY

Detailed fuel finder.

Petty is a simple fuel price tracker that covers NSW, QLD, and TAS – utilising those state's free APIs to dynamically show fuel prices across your local area. However it only uses the government database, meaning some of the prices may be out of date – especially with independent fuel stations that tend to report their prices manually.

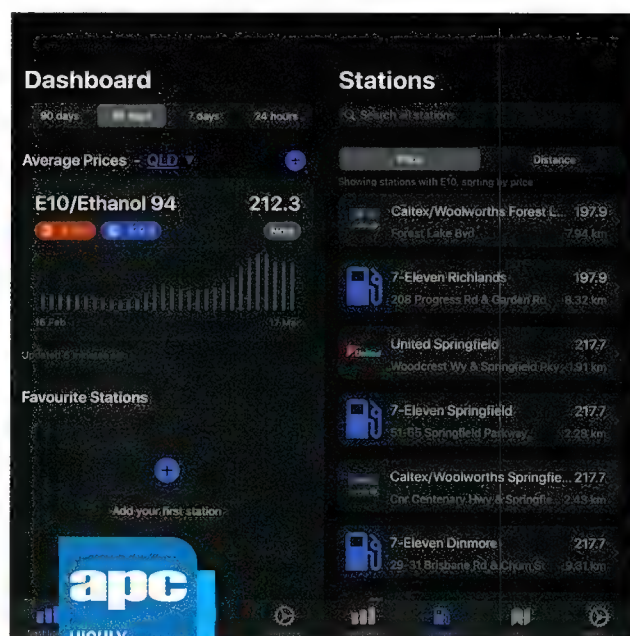
The interface is clean and easy to navigate, and I appreciate there being both an easy-to-use list and

map. There are also 24hr/7d/30d/60d charts of prior fuel pricing to assess trends, complete with graphs.

Petty does offer a monthly subscription for more detailed pricing information, which is quite cheap (\$5/year with a trial week), which allows for more detailed graph information and tracking of multiple fuel types.

★★★★★
James Pinnell

Petty is a simple fuel price tracker that covers NSW, QLD, and TAS – utilising those state's free APIs to dynamically show fuel prices across your local area.



ArchLabs has customised all of the desktops it bundles. This is its rendition of the Deepin DE.

apc
HIGHLY
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ArchLabs 2022.02.12

Mayank Sharma has a soft spot for new Arch-based distros, and this time around he's found one that tickles his fancy.

Over the years, the ArchLabs distro has deviated considerably from its origins. It now suits users who want to exploit Arch's famed customisability to build their installation from scratch, but with some added conveniences to minimise the time it takes to deploy a pure Arch system.

ArchLabs caters to users who aren't afraid of the command line, but want to run a desktop distro without spending a lot of time to compile everything from scratch. Unlike some of the other popular Arch-derivatives, the 64-bit only distro doesn't boot into a Live environment. Instead, its install-only medium takes users to its text-based installer dubbed AL-Installer. It's fairly straightforward to navigate and includes all the conveniences of a modern distro installer, without the bloat.

The installer helps users navigate through the various installation steps, and offers plenty of options. For instance, the installer includes various popular partitioning tools, but also extends the option to automatically partition the disk, which is useful if you only want ArchLabs as the sole distro on the machine.

The installer also offers bootloaders, shells and a range of kernels. There's the vanilla kernel on which the developer has applied a few patches. Then there's the long-term support (LTS) kernel, and

a security-focused kernel with patches to mitigate exploits. These will be handy if you want to use ArchLabs to host servers or critical applications. If you want to run your ArchLabs installation as a regular desktop, you can use the Zen kernel that's been optimised for everyday desktop use.

Similarly, the installer gives the user the ability to choose from over a dozen different desktop environments and window managers. There's everything from heavyweight desktops like Gnome, and Deepin, to lightweight ones like Xfce, and LXQt, and barebones window managers like Sway and JWM.

In its first release of 2022, the distro has added a new custom window manager christened dk. This is described as a list-based tiling window manager, much like dwm, bspwm and xmonad.

Based on Arch, the distro inherits one of the best package management systems in the game. It supplements this by rolling in its own Arch User Repository (AUR) helper script dubbed baph for Basic AUR Package Helper. AUR Helper scripts enable users to search for packages published in Arch's community-driven repository, helping them resolve dependencies, before retrieving and building them.

The Arch project doesn't recommend using AUR helper scripts, and instead suggests users build all their packages

manually. However, baph didn't throw any errors, and helped us install everything from office suites to games without any issues.

If we have to be picky, the one issue we'd like to flag doesn't exist in the distro, but rather in the project – namely documentation. The project has just enough documentation to help new users familiarise themselves with the distro, but there's not enough of it to help first-timers orient themselves with the ways of ArchLabs.

Although ArchLabs is designed for users who've clocked enough mileage with Linux to be able to find their way around the distro, we think the project needs an updated 'getting started' guide for the mere fact that it's metamorphosed into a completely different beast than what it eventually set out to be. The distro has been dishing out releases for half a decade now, and has been covered extensively. However, much of the information out there isn't relevant thanks to the distro's constant evolution.

Want an easy-to-install Arch-derivative with minimal bloat and maximum choice? Then consider ArchLabs.

★★★★☆



CHROMEBOOK OR WINDOWS LAPTOP?

Are Chromebooks the revolution the laptop space needs or will Windows emerge triumphant? Christian Guyton explores.





Chromebooks – plucky little brother to the Windows laptop, typically trading performance for portability and ease of use. An affordable option for performing basic tasks such as word processing and web browsing. While Chromebooks may be disparaged by tech-heads, they've come a long way since their introduction in 2011. Google describes today's ChromeOS laptops as 'speedy, simple and secure', with virus protection built-in and effective cloud-based storage for files and user data.

So, how do modern Chromebooks compare to their Windows counterparts? We break down some of the best ChromeOS systems on the market right now – it's about more than just performance, of course; value, ease of use, portability, and general hardware quality will all be factors. Will Chromebooks emerge victorious or should we stick to what we know best?

While Chromebooks may be disparaged by tech-heads, they've come a long way since their introduction in 2011. Google describes today's ChromeOS laptops as 'speedy, simple and secure', with virus protection built-in and effective cloud-based storage for files and user data.



OS	ChromeOS
Processor	Intel Core i3-1110G4
Graphics	Intel Iris Xe
RAM	8GB LPDDR4X
Storage	128GB NVMe SSD
Display	14-inch FHD (1920x1080) IPS, 16:9 aspect ratio, 60Hz refresh rate
Connectivity	Wi-Fi 6E, Bluetooth 5.2, USB-C, USB-A, 3.5mm audio jack
Battery	42Whr, up to 10 hours
Size	12.2 x 8.7 x 0.6 inches
Weight	2.8 lbs

\$1,199 | [asus.com](https://www.asus.com)

Asus Chromebook Flip CX3400

Despite being a relatively high-end model, the Asus Chromebook Flip CX3400's \$1,200 price tag puts it closer to the budget space, adrift in a market dominated by slick MacBooks and \$2,000+ gaming laptops. The Flip CX3400 needs to justify its price tag since it occupies that space between more powerful Windows laptops and more affordable Chromebooks.

Out of the box, it's off to a strong start. While Chromebooks have been price-sensitive machines, a design ethos that all too frequently extends to the build quality of the external casing, the Flip CX3400 feels premium. It's the heaviest of the three Chromebooks on test here and the largest too. The blue-tinted exterior looks great, with shiny metal hinges that feel remarkably sturdy.

That's a good thing given that this is a 2-in-1, with a gorgeous 14-inch touchscreen. The display is easily the brightest and most colourful of these Chromebooks and feels good to use in tablet mode. ChromeOS lends itself better to the hybrid laptop design than Windows 10 or 11, automatically switching from the conventional desktop mode to a smartphone-esque grid of apps when you convert it into the tablet configuration.

The 16:9 widescreen aspect ratio isn't ideal for productivity, but that's a matter of personal preference. We were a little concerned about the screen and matte

casing picking up fingerprints, but it wasn't anywhere near as much of an issue as we had expected. If you're particularly smudge-phobic, there's a slot for an integrated stylus on the right-hand edge of the chassis. This isn't anything special and can be swapped out for any compatible smart pen if you prefer more control.

The keyboard is decent, broadly comparable to any laptop keyboard in the same price bracket, with bright white backlighting and a good amount of travel for a tactile typing sensation. The trackpad is where the whole setup falls down; it feels flimsy, with too much surface friction and an unsatisfying click. It can be converted into an LED-illuminated numpad at the press of a button, though, so we'd recommend leaving it in that mode and using a wireless mouse (or the touchscreen itself).

In terms of performance, the Flip CX3400 dominates the other Chromebooks thanks to its 11th-gen Intel Core i3 processor, offering solid performance in both single-core and multi-core workloads. There's a table with benchmark results at the end of this article, but with few tests that can be effectively run on both Windows and ChromeOS, we've used the multi-platform benchmark Geekbench 5 along with 'Aquarium', a WebGL test that renders up to 30,000 animated fish.

Although it doesn't have Intel's shiny new Iris Xe integrated graphics, the i3-1110G4 CPU performs well in the WebGL test, outstripping the Lenovo IdeaPad Flex 3 and Acer Spin 513 Chromebooks and placing itself among the Windows laptops we were testing. With a bit of Linux meddling, we were able to get a few Steam games running on the Flip CX3400, albeit non-graphically-demanding ones.

The speakers on the Flip CX3400 are underwhelming, and though we'd advise using a headset anyway, the audio was tinny and not especially loud. The battery is a bigger issue; Asus suggests 'up to 10 hours' of battery life, but testing at 50 percent brightness barely gave us six hours of continuous use.

Overall, the Flip CX3400 is the best of the three Chromebooks we've looked at here – but it's also the most expensive. We're not convinced it does enough to justify its price tag, especially since better performance is available in Windows laptops at the same cost. Despite that, it's a well-designed product that effectively demonstrates the best of what Chromebooks can be.

Stylish physical design and good CPU performance with a great screen.

★★★★☆



OS	ChromeOS
Processor	Intel Celeron N3050
Graphics	Intel HD Graphics
RAM	8GB
Storage	64GB eMMC
Display	11.6-inch FHD (1366x768)
Connectivity	Wi-Fi, Bluetooth, USB-C
Battery	42Whr
Size	11.6 x 7.7 x 0.7 inches
Weight	2.2 lbs

\$400 | lenovo.com

Lenovo IdeaPad Flex 3

If you've got kids in your life, this Chromebook encapsulates the focus on education Google had when creating ChromeOS. Plenty of Chromebooks are aimed at schoolchildren, so it would have been remiss of us not to include one in our breakdown.

The IdeaPad Flex 3 is, if we're being honest, a bit ugly. The exterior is rubberised plastic with a grippy textured finish, which looks bad but is ultimately designed for small hands and a laissez-faire attitude to hardware safety. It feels durable; you could throw this Chromebook into a locker or backpack without having to worry about protection. The 360-degree hinge feels similarly robust.

Unlike every other device featured in this article, the IdeaPad Flex 3 doesn't have an FHD display. Instead, the small, 11.6-inch display operates just above 720p, at a resolution of 1366x768. The dark screen bezel is excessively chunky, in our opinion, and while colour reproduction and brightness are okay, this display is definitely nothing to write home about.

In terms of internal components, the IdeaPad Flex 3 isn't particularly exciting. We've got an Intel Celeron processor, a sensible 8GB of RAM, and a reasonably powerful battery that provides decent longevity given the smaller display; continuous video playback

at 50 percent brightness saw the battery give out just shy of ten hours from a full charge. The Celeron CPU isn't going to win any races, but ChromeOS is well-optimised for lower-end hardware so we didn't see any noticeable lagging in everyday use.

One area where the IdeaPad Flex 3 falls down is the drive; it's an eMMC drive with just 64GB of storage space, the same as the Acer Chromebook Spin 513. This being a Chromebook, you're expected to use cloud-based storage, but for anyone who wants to store files locally, it's not likely to be sufficient. An even cheaper version exists, with the same CPU but only 4GB of memory and a measly 32GB of storage. Both versions come with an integrated stylus, which feels comfortable to hold in the hand; ideal for taking quick notes in class.

Benchmark performance isn't impressive, but that's hardly surprising given the low-powered processor. Graphical performance is by far the weakest of the devices on test here, with WebGL Aquarium looking a bit like a slideshow. Simple app games from the Android Play Store (now supported on most Chromebooks) will run fine but don't expect much more.

Of course, we've got all the performance needed for this

Chromebook's intended purpose. Sixth-grade science homework will be no trouble for the Celeron, with simple tasks (like web browsing and word processing) being just fine. It's perfectly capable of a bit of YouTube or Netflix too, although the tiny screen and lackluster speakers make it a poor alternative to a TV.

Unusually for a laptop, the IdeaPad Flex 3 has two separate cameras. The main 720p webcam is situated at the top of the screen, where one would expect to find it, while a second 5MP camera nestles above the keyboard. This allows the user to take photos or video while using the IdeaPad Flex 3 in tablet mode, functioning as a 'rear' camera. Yes, you'll look like this writer's dad attempting to take holiday photos with his new iPad in 2010, but it works.

Ultimately, the Lenovo IdeaPad Flex 3 does a good job of fulfilling its purpose as a basic, easy-to-use laptop for pre-uni students. It's unlikely to appeal to adults (or even older teens) but it functions just fine and has the durability to survive the rigors of being used by a child. No, it isn't exciting, sleek, or powerful, but it's fit for the task it was designed for.

Good battery life in a rugged design that's affordable, but limited local storage.

★★★★☆



OS	ChromeOS
Processor	Qualcomm Snapdragon 7c
Graphics	Adreno 618
RAM	4GB LPDDR4X
Storage	64GB eMMC
Display	13.3-inch 1080p IPS
Connectivity	Wi-Fi 6, Bluetooth 5.1, USB-C, MicroSD
Battery	4300mAh
Size	11.7 x 7.7 x 0.6 inches
Weight	2.8 lbs

\$560 | acer.com

Acer Chromebook Spin 513

Though the Acer Spin 513 sticks to the Chromebook script, with its touchscreen, hybrid tablet design, and underpowered speakers all par for the course, where the Spin 513 differs is its processor; rather than an Intel chip, this Chromebook uses a Qualcomm CPU.

The Spin 513 is powered by Qualcomm's new Snapdragon 7c processor, an octa-core CPU that promises to deliver industry-standard performance with Adreno integrated graphics while improving battery life and reducing heat generation.

It's an ARM-based chip, and ChromeOS is well-optimized for ARM, as are the Android apps available through the Play Store on every Chromebook. However, users who want greater flexibility to run virtual Linux environments are likely to run into compatibility troubles with some Linux apps.

In terms of overall specs, the Spin 513 isn't immediately impressive. A modest 4GB of RAM is joined by a dinky 64GB eMMC drive, the latter presenting the same problems for local storage as the Lenovo. The battery is a 2-cell lithium-ion affair; one less cell than those seen in the other Chromebooks on test here, though that shouldn't be an issue, given the Snapdragon processor's lower power draw.

Those figures make sense when you consider that the Spin 513 costs just a

few dollars more than the 500e. Other areas are more impressive than Lenovo's child-friendly Chromebook, with a 13.3-inch 1080p display offering good brightness and colour clarity. The screen shows up fingerprints if used heavily in tablet mode, though.

Build quality is also solid, while still managing to look good. It hasn't reinvented the way laptops look, but its matte silver exterior and small screen bezel mean it looks just as good as pricier Windows notebooks. The hinge feels secure when switching between tablet and laptop modes, and there's little flex to be felt in the plastic casing while typing or using the trackpad.

There's not much to say about the Spin 513's keyboard. As with most thin and light laptops, there's little travel and the keys will feel spongy to anyone used to typing on a mechanical keyboard, but overall it's fine. The trackpad, on the other hand, is the best of the three Chromebooks we tested. A Gorilla Glass coating means it feels both smooth and durable, with a satisfying click to boot.

Performance-wise, the Spin 513 manages what we expected from a Snapdragon processor. The Adreno 618 graphics are perfectly sufficient for app games and general use, and CPU performance is comparable to the Intel Celeron chip found in the Lenovo IdeaPad Flex 3. Provided you aren't opening too many Chrome tabs at once,

you shouldn't see any slowdown. However, the 7c is still far behind any of Intel's Core processors, even lower-end i3s, and the paltry amount of RAM doesn't help considering ChromeOS's memory-guzzling tendencies.

The Snapdragon chip's lower power requirements provide some boons. In the same battery test used for the other Chromebooks, the Spin 513 managed over 13 hours of continuous operation, offering the sort of 'all-day' battery life professional users have been craving. The reduction in excess heat production also means no fan noise, making the 513 the quietest of all the devices in this article.

It has a familiar selection of ports including two USB-Cs (one of which is also used for charging). The MicroSD card reader found on the other two Chromebooks is conspicuous in its absence here, though that will only be a concern for a few potential buyers.

At its price point, the Acer Spin 513 is one of the better Chromebooks available right now, but it's perhaps not the poster boy for ARM-based CPUs that Qualcomm hoped it would be.

Excellent battery life and it runs super quiet, but performance is average.

★★★★☆



OS	Windows 11
Processor	AMD Ryzen 3 4300U
Graphics	AMD Radeon Graphics
RAM	8GB DDR4
Storage	256GB PCIe NVMe M.2 SSD
Display	15.6-inch IPS LCD, 1920 x 1080, 60Hz
Connectivity	Wi-Fi 6, Bluetooth 5.0, 2x USB-A, 1x USB-C, 1x RJ45
Battery	41 Whrs, 4-cell Li-ion
Size	14.1 x 9.8 x 0.7 inches
Weight	3.75 lbs

\$1,199 | hp.com

HP Pavilion 15

HP's Pavilion 15 range is broad, with models ranging from this sensible budget model to more powerful iterations with dedicated GPUs. This version is a reserved affair, with a Ryzen 3 4300U processor, 8GB of DDR4 memory, and 256GB of speedy NVMe storage.

The Pavilion 15's defining feature is right there in the name: a lovely 15.6-inch touch panel, offering excellent brightness and plenty of screen real estate for productivity-focused users. The large display means a bigger overall size, so we've got a full-sized keyboard complete with numpad crammed in here too, as well as a nice wide trackpad that handled better than we'd expect for a \$1,200 laptop.

Despite the size, this is by far the cheapest of the Windows laptops on test here. It's not hard to see where HP has opted to trim the fat to save precious manufacturing dollars; there's no keyboard backlighting, and the chassis is entirely plastic. It's fairly heavy and won't fit as easily in a shoulder bag, but with the lid closed it's almost as thin as the competing laptops - thinner, in fact, than the chunky Lenovo IdeaPad Flex 3.

There's a relatively generous selection of ports to choose from, notably including HDMI, an increasingly rare sight on thin budget laptops. Note that this HDMI out is best used simply for hooking up a larger display for

presentations or videos, not for gaming or regular dual-screen use. The Ryzen 3 chip inside this Pavilion 15 goes without discrete graphics, relying instead on its Radeon iGPU.

It's fair to say that high-level gaming and creative workloads aren't really on the table here, although the Radeon Graphics did alright in our hardware-accelerated WebGL test. Day-to-day use with a bit of light indie gaming is not likely to pose any problems. The 4300U handled itself well in the single-core Geekbench 5 test, but multi-core performance was significantly less impressive. Still, for general productivity tasks, this Pavilion 15 shouldn't run into any trouble.

It's also remarkably quiet and cool, perhaps thanks to the lower-spec processor. Our other laptops were a little noisier during benchmarking, while the Pavilion gave barely a fan-whisper. Provided you ensure the vents remain unblocked (that means no using it in bed!) the thermal performance is great.

One might hope that the lower-spec components would mean that this laptop's battery life could stretch for a little longer, but unfortunately that isn't the case. Although the fast-charging function works well, filling to a full charge from empty in under an hour, that big display drains the

tank fast and HP evidently had to scale back battery capacity to keep the price down. Continuous video playback at 50 percent brightness saw this Pavilion give up the ghost after just six hours and 20 minutes.

We've certainly seen worse battery longevity (cough, gaming laptops, cough), but we'd really like to see better from a productivity-focused machine. Whatever the large screen says, this isn't meant to be a desktop replacement, so good battery life for a nine-to-five in the office and on the go is essential.

Battery aside, we have to admit that the Pavilion 15 certainly looks like a high-quality product regardless of its lower asking price. It's a big, bold design in striking silver, with matching keycaps and a pleasingly shiny HP logo on the back of the lid.

Although the chassis might be all-plastic in composition, it doesn't feel flimsy. Typing felt good, with the best key travel and little flexing even on firm button presses.

For \$1,200, you could do a lot worse than this Pavilion 15 - though we can't help but wonder if the more expensive versions packing Intel's 11th-gen CPUs might be a better shout for most.

Quiet and cool with a nice big screen, reasonably priced. Poor battery life.

★★★★☆



OS	Windows 10
Processor	AMD Ryzen 7 5700U
Graphics	NVIDIA GeForce RTX 1650
RAM	16GB (DDR4)
Storage	512GB PCIe NVMe SSD
Display	14-inch IPS (1080p)
Connectivity	Wi-Fi 6, Bluetooth 5.1, USB-C, USB-A, HDMI
Battery	48Whr (up to 17h)
Size	12.5 x 9.0 x 0.7 inches
Weight	3.33 lbs

\$1,598 | acer.com

Acer Swift X

The Acer Swift series of notebooks has been around for a while, but the Swift X is a step forward for the manufacturer. While previous Swift models ran the gamut of budget to premium, the Swift X is looking to be all things to all people – discrete graphics for gaming and creative tasks, a powerful Ryzen 5000 CPU, all-day battery life, and a sleek, lightweight form factor.

In terms of physical design, at least, it holds up to this ethos well. It's certainly not the thinnest nor lightest ultrabook on the market, but it's perfectly portable at 3.33lbs and keeps its screen bezel small despite a decently sized 14-inch display. This LCD IPS panel isn't a touch screen, unlike the other laptops it's up against, but it's a nice screen nonetheless; colour reproduction and contrast are excellent, and the matte finish means it functions well in brightly lit environments.

The exterior casing is machined aluminum available in a variety of colours, while inside the lid we've got plastic construction. Opening up the Swift X sees the screen base push the bottom half of the chassis upwards slightly, improving the typing experience by angling the keyboard towards the user. The keyboard is a bit soft, with a mushy feel to the keys and too much flex in the casing on firm key presses. The trackpad is better, with a smooth surface and a robust, responsive click.

All the usual aspects of a modern

mid-range notebook are here, from the standard 720p front-facing webcam to a fingerprint scanner for Windows Hello logins. There is the same selection of ports offered by the HP Pavilion 15, too; two USB-A's, USB-C, HDMI, and an audio jack.

One unusual design choice is the single-fan cooling system, which vents exhaust heat towards the screen, at the top of the keyboard. During benchmarking, the Swift X felt the warmest of the laptops we tested, although the lone fan meant that it was also quiet even mid-benchmark. Internal temperatures didn't reach concerning levels, but this isn't a laptop you'll want on your lap for long periods.

Our review model of the Swift X is one of the more affordable ones, with a powerful Ryzen 7 5700U processor and a slightly less impressive GeForce GTX 1650 graphics card. These are joined by 16GB of soldered RAM and half a terabyte of high-speed M.2 SSD storage.

It's a capable setup, with a fantastic performance in multi-core workloads and rapid file transfers. WebGL performance wasn't amazing, but the dedicated GPU can handle intermediate-level creative workloads and most games will run fine at 1080p with medium to high graphics settings.

But the three-year-old GTX 1650 is looking a bit dated now; add a couple of hundred bucks onto the price and you

can get a Swift X with a newer RTX 3050 or 3050 Ti, which should offer between 15 and 35 percent better performance with little impact on the battery life or thermal management. Yes, this model is cheaper, but we would question the logic behind buying a 1650 model when 3050 versions are in the same ballpark.

Acer suggests that the Swift X can get up to 17 hours of continuous operation, which we're calling bull on (unless you fancy squinting at your idle desktop with minimum brightness all day). Still, our testing saw it survive well past the ten-hour mark, ensuring that you won't run dry during a busy workday.

Ultimately, this is a solid all-rounder laptop for under \$1,600. Yes, you could easily get better performance at this price point, but not without sacrificing either its compact nature or its lengthy battery life. The Swift X is an effective tool for both work and play, an excellent choice of laptop for the busy creative or office worker who likes to squeeze in a bit of gaming on the train journey home.

5700U CPU is excellent, good display, battery life is solid. Runs hot under load.
★★★★☆



OS	Windows 11 Home
Processor	Intel Core i7-1185G7
Graphics	Intel Iris Xe Graphics
RAM	16GB LPDDR4x-4267
Storage	512GB PCIe NVMe SSD
Display	13.5" FHD+ (1920x1200) IPS, 16:10 aspect ratio, 400 nits brightness
Connectivity	Wi-Fi 6E, Bluetooth 5.2, 2x Thunderbolt 4 ports, 2x USB-A ports, 1x USB-C port
Battery	51Whr, up to 10 hours
Size	11.5 x 7.7 x 0.6 inches
Weight	1.35kg

\$2,839 | msi.com

MSI Summit E13 Flip Evo

At over \$2,800, this is the most expensive product on this list. It's still decidedly mid-range as laptops go, although you'll struggle to spend that much money on a Chromebook. The Summit E13 Flip Evo works hard to justify its pricing, with some dedication on MSI's part to make it feel like a premium ultrabook with a hybrid tablet design aimed at fast-movers.

The Flip Evo is an eye-catching product, with a golden trim surrounding the edges of its black, machine-milled metal exterior. It's thin and compact, reminiscent of pricier convertibles such as the Asus Zenbook Flip 14 or the HP Spectre x360.

Despite its diminutive stature and mid-range pricing, the Flip Evo has an exceptional display, using a 16:10 aspect ratio with a 1920x1200 resolution (which MSI calls FHD+, although that's technically 2220x1080). That 'golden ratio' means there's plenty of display space for productivity and web browsing, and it's a reasonably colourful panel with good maximum brightness. It's a touchscreen too, and while the bezel is far from the thinnest we've seen, it's not too chunky. The 16:10 ratio and thick bottom edge mean that the Flip Evo is a bit cumbersome to hold in tablet mode, but this won't be a concern for most users.

Aside from the gorgeous display, one major selling point of the Flip Evo over

its rivals here is the inclusion of the MSI Pen, a sleek and lightweight smart stylus that snaps magnetically to the edge of the laptop when not in use. It's ideal for sketching or note-taking and though not as sophisticated as devices such as the Apple Pencil, palm rejection is reliable and sensitivity is good.

The trackpad is on the small side, which might be an issue for some users, but it feels good to use with a soft surface texture and firm click. The keyboard is also decent; more expensive laptops offer better typing experiences, but the keys have a reasonable amount of travel and don't feel too spongy. The keys are backlit in a soft white that wraps around the edges of each keycap, giving the layout a well-defined appearance.

The internals of this laptop don't fail to impress either. We've got a powerful Intel Core i7-1185G7 processor with Iris Xe integrated graphics, backed up by 16GB of speedy memory. Although it doesn't quite match the Ryzen 7 CPU in the Acer Swift X for multi-core performance, it dominates single-core workloads and the Xe graphics are good enough for some light gaming on the Flip Evo's lovely screen. It doesn't get too hot either, thanks to two powerful fans – although during demanding operations they do get a

little bit noisy.

The drive is a speedy M.2 SSD with 512GB of storage, which should be more than enough for the average user. There's also an array of physical ports, from standard USB-A to a pair of Thunderbolt 4 ports, which allow for display daisy-chaining, high-speed transfers, and fast-charging. The Flip Evo also has ultra-low-latency Wi-Fi 6E, the first laptop of its kind to feature it.

Battery life is also good, although it falls short of MSI's suggestion of 20-hour productivity. Practical testing saw the battery last for a little over nine hours from a full charge, which is sufficient for a day's work. Other features include a familiar 720p webcam, a fingerprint scanner, and speakers that are good, if lacking in bass.

Ultimately, it's a little pricey given its performance capabilities. But it's difficult to dislike the Summit E13 Flip Evo. It's a genuinely well-designed hybrid laptop free from the bloatware crammed in by OEMs like HP, with a designer aesthetic and good all-round performance.

Fantastic display, keyboard and trackpad,
MSI Pen is great, gorgeous design.
★★★★★

Conclusion

When you spend your work hours drooling over high-performance hardware, Google's sensibly-priced, security-focused laptops aren't exactly a turn-on. But Chromebook design has come a long way from its origins (check out that Acer AC700, for instance!). Modern Chromebooks can match mid-range laptops for aesthetics; the Asus Chromebook Flip CX3400 is the perfect example, combining thin-and-light design requirements with a clean, refined look. While older Chromebooks looked most at home in the IT rooms of elementary schools, cash-strapped university students no longer need to feel ashamed by their hardware if they opt for Chrome.

If you're on a tight budget or looking for 'Baby's First Laptop', Chromebooks just make sense. They won't break any performance records, but ChromeOS is so well-optimised for low-end hardware at this point that these laptops can do a lot with a little, covering all the bases from surfing the net to watching Netflix. Gaming still remains out of reach for most Chromebooks, but that's largely alright considering that PC gaming is still more the domain of over-18s (a 2020 study by the ESA found that children are more likely to play games on a home console, handheld, or smartphone). App games via the Play Store are still an option too, and with mobile gaming booming, those games are genuinely



The 2012 Acer AC700 Chromebook helped pave the way.

improving in quality. There are still plenty of low-quality, microtransaction-riddled cash-grabs, but indie PC hits such as Slay the Spire and 80 Days mean that fine gaming experiences are definitely not in short supply on ChromeOS.

Beyond the Play Store, we did a bit of software gymnastics to get Steam running on these Chromebooks, just to see what our options were. This can be done in two ways; the first is simple, using Valve's Steam Link app to turn your laptop into a streaming platform. This requires a separate PC from which to stream your games, so you'll need a gaming PC at home for this. Steam Link is a functional (if occasionally buggy) tool, but it pales in comparison to proper

game-streaming services such as Google Stadia and Nvidia's GeForce Now.

The other option is more complicated. By using the beta developer tools available in the current version of ChromeOS, you can install a Linux environment on your Chromebook, which allows you to run Steam locally without the need for Steam Link. This uses the Chromebook's own hardware, which has drawbacks. Stardew Valley and Terraria ran fine, but games with 3D graphics aren't really an option; we tried testing XCOM 2 without much luck. We managed to get Portal 2 running on the Asus Flip CX5 with a

AND ALL THE REST

There were plenty of Chromebooks we would have loved to feature in this article but couldn't due to time constraints or hardware availability.

The big one was Google's own Pixelbook Go, a premium Chromebook that offers the best of what the platform can do. The Go features a sturdy but thin design, stellar battery life, and one of the best keyboards found on any notebook laptop. Higher-spec models also offer a 1080p webcam and even a 4K touch display.

We'd also point the ChromeOS curious towards Lenovo's IdeaPad Duet, a Chromebook with a detachable keyboard for a true tablet experience. The Duet's hardware specs are modest (4GB of RAM and a MediaTek

ARM processor) but given its sub-\$450 price tag, we can't be too critical.

HP's Chromebook x2 11 also uses a detachable keyboard but ramps up the quality with a 1440p touchscreen and fingerprint scanner built into the power button. It's powered by the same new Snapdragon 7c processor from Qualcomm that we saw in the Acer Spin 513, which feels more at home in a tablet than a regular laptop. We should be getting one soon, so keep an eye on our reviews section.

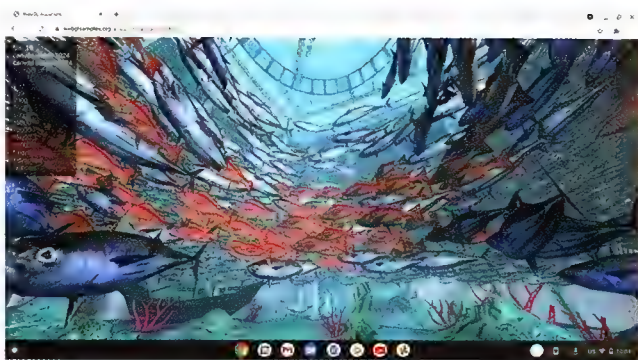
Another affordable option is Acer's 515, which snubs the



Google's own Pixelbook Go is an Intel-powered Chromebook that showcases the best of what the platform can do.

convertible design of most current Chromebooks for a 180-degree hinge that keeps things simple. No bells and whistles here; no stylus, no IR camera, just reliable performance and a powerful

battery for all-day use. Its all-aluminum exterior ensures durability, and it's bundled with a mouse so you don't have to use the basic trackpad. In other words, it's a laptop for people who don't like laptops.



The WebGL-powered Aquarium test is a good way to check the graphical performance of low-powered machines.

dismal framerate, but it refused to boot at all on the other Chromebooks.

Of course, plenty of games available on Steam aren't set up for Linux compatibility. Using Steam's own Proton Experimental Steam Play function, you can potentially run Windows titles that won't normally run natively on Linux platforms. However, this only works for a limited number of games, and you'll still be bound by the restraints of your Chromebook's local hardware.

Hardware aside, ChromeOS is a far more powerful operating system than it used to be. Gone are the days of slow internet hamstringing the entire platform, and navigating the menus of the OS is a process that has been streamlined to result in a genuinely pleasant experience. The 'Everything Button' present on every new Chromebook is also a nifty addition, allowing you to search the web and your local device for whatever you need.

With all that said, we still prefer Windows. It's a platform that allows for greater flexibility and customisation, with support for the broad range of applications that tech-heads need. While the Windows laptops we featured here were running Windows 10, all are eligible for a free upgrade to Windows 11 and will come preloaded with the newer

OS if you buy them new. The burning question that we're left with is this: where do Chromebooks go next? The inevitable continuation of refining both the OS and the physical hardware is one thing, with Chromebooks swiftly catching up to conventional laptops in appearance, but can we expect to see Chromebooks seize even more of the market share away from Windows? In 2020, Chromebooks overtook MacBooks for the first time in sales volume, largely by eating into Windows laptop sales rather than consuming Apple's market share. Sure, this leap was driven by the pandemic forcing students and office workers into studying and working from home, but sales figures have remained strong and introducing a young generation to the ChromeOS platform is likely to work well for Google in the future.

Indeed, targeting a younger audience and doubling down on its focus on Chromebooks as a tool for education could be the way to go. Over 30 million Chromebooks were shipped in 2020, many of which went to students or directly to schools. In 2018, Chromebooks accounted for more than 60 percent of computers in US schools. Security features are a big draw; not only is ChromeOS less likely to be targeted by

virus attacks than Windows computers (for now), but Google's design ethos included strong security measures. User error is the most common cause of digital security breaches, and ChromeOS has design choices built-in to minimise opportunities for users to mess up.

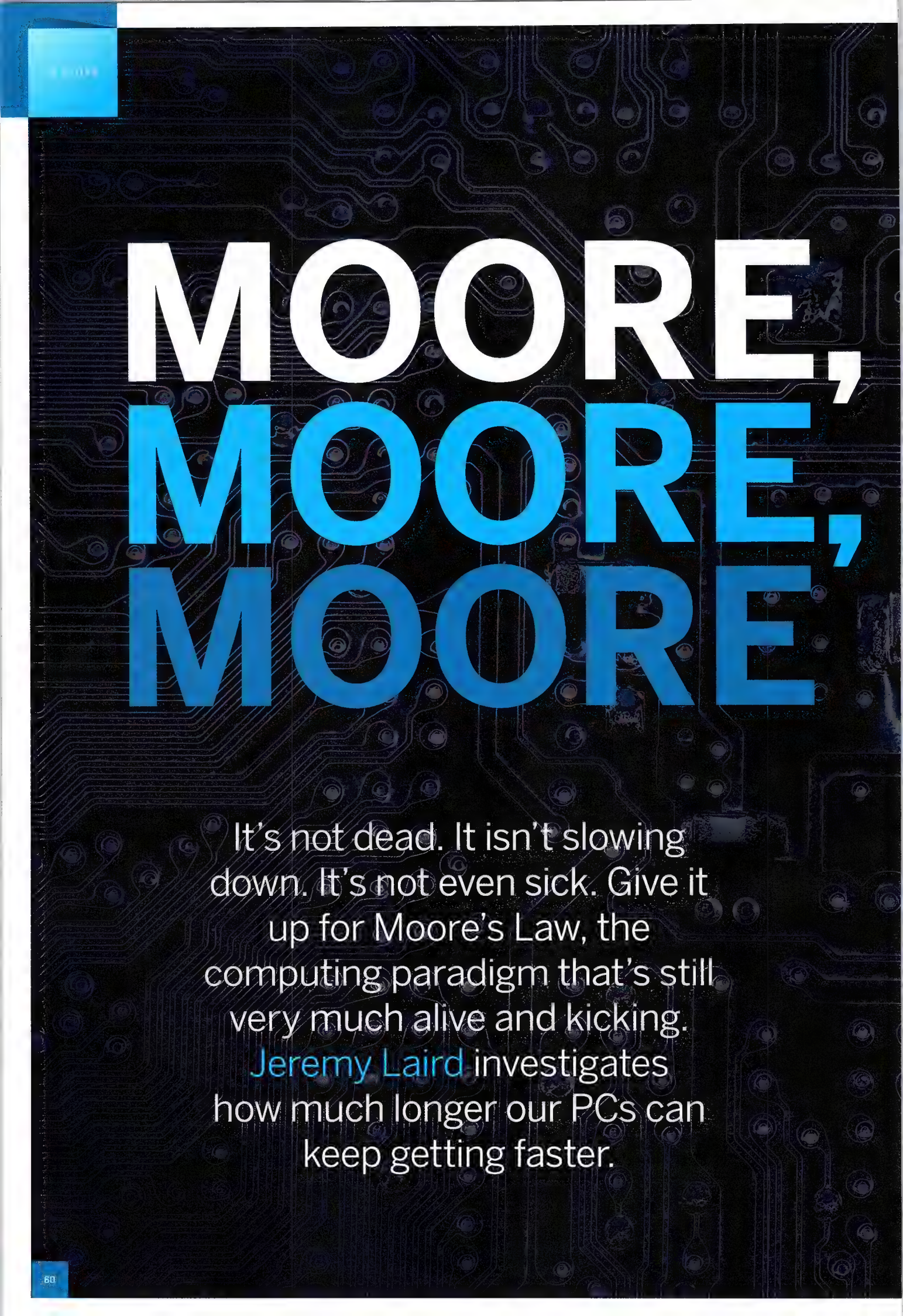
Though not the silver bullet for online security that Google would like you to think, Chromebooks are undeniably a safer and more streamlined way to introduce children to the digital world. Many kids' first encounters with technology are their parents' phones and tablets, so ChromeOS offering a familiar Android-enabled environment makes perfect sense. Upon first setting up a new Chromebook, you'll be given the option to set up a child-friendly profile, which allows a parent to easily set safety limits.

For adults, Chromebooks still have their advantages, but we're not convinced they're a viable competitor to Windows – not yet, anyway. They're improving fast, arguably faster than laptop hardware, which is beginning to stagnate. In another five years, the market could be in a different place, with Chromebooks potentially securing dominance thanks to their wallet-friendly pricing and idiot-proof software. Needless to say, we're curious to see what happens next. ■

BENCHMARKS

Chromebooks and Windows laptop by the numbers

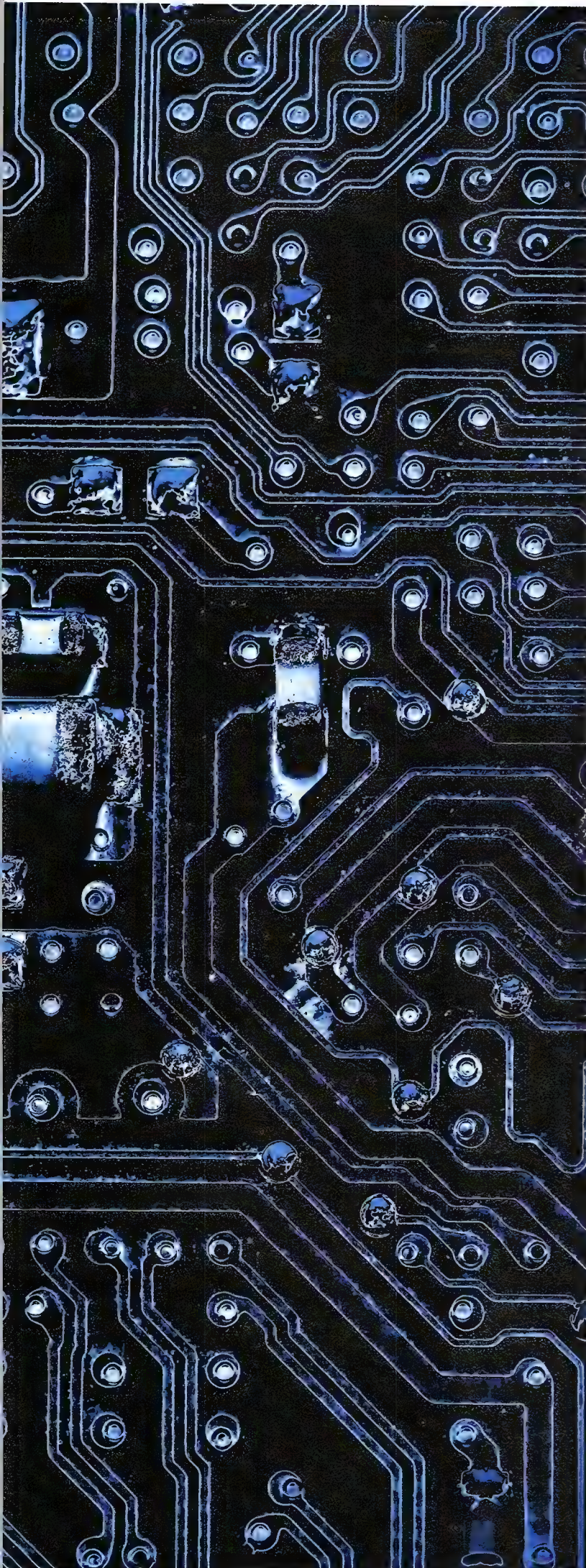
	Geekbench 5 (single-core index)	Geekbench 5 (multi-core index)	WebGL Aquarium 30000 (fps)
Asus Chromebook Flip CX5	1,196	4,689	25
Lenovo 500e Chromebook	499	1,591	3
Acer Chromebook Spin 513	533	1,572	9
HP Pavilion 15	992	2,830	25
Acer Swift X	1,183		20
MSI Summit E13 Flip Evo	1,451	5,379	



MOORE, MOORE, MOORE

It's not dead. It isn't slowing down. It's not even sick. Give it up for Moore's Law, the computing paradigm that's still very much alive and kicking.

[Jeremy Laird](#) investigates how much longer our PCs can keep getting faster.



By some estimates, over half of the world's economic growth over the last 50 years has depended on Moore's Law. What was once an esoteric observation involving transistor density in semiconductors is arguably now the most important economic driving force on the planet. It's the technological gift that keeps on giving. More transistors. More computing performance. For less money. Year after year.

The net result has been unprecedented global economic growth lasting decades. In other words, Moore's Law isn't just about faster CPUs and GPUs every year or the inevitability that the PC you buy today will be hopelessly outclassed tomorrow. It's about the huge impact that exponential increases in computing power have had on the way we all live.

At least, that was true for about 40 years following the inception of Moore's Law in the mid-1970s. Over the past decade, however, the assumptions around Moore's Law have been shaken, some argue shattered. Certainly, some of the biggest players in chip production have struggled to maintain the relentless technological cadence implicit in Moore's Law. Five or six years ago, the widespread assumption was that Moore's Law was well on its way to becoming as dead as the dodo.

Today, however, it's a bit more complicated than that. The big boys in chip production, including Intel, TSMC, and Samsung, all have aggressive roadmaps involving ever smaller chip nodes that look conspicuously Moore-ish. TSMC in particular has a recent track record for actually delivering. So, is Moore's Law back on course after a temporary blip? Or are its death throes merely being dragged out a little longer than expected? Time to find out.

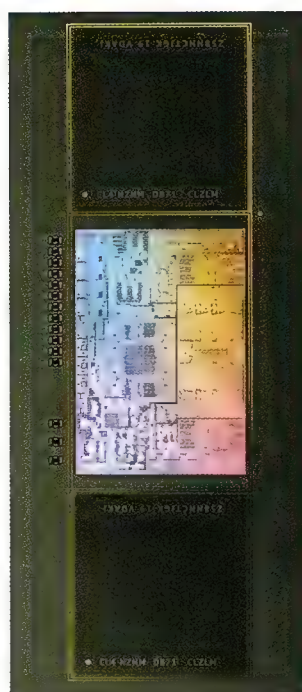
To begin, let's reflect on what Moore's Law actually is. It comes down to the disarmingly simple observation that transistor densities in integrated circuits double every two years. In other words, Moore's Law says that twice as many components are squeezed into a given area of computer chip every couple of years. This is the pace at which the chip industry has progressed for decades and the result, in hardware terms, has been spectacular, exponential growth in computing complexity and capability.

If that seems to also imply a halving in cost over the same time frame, the reality isn't quite so simple. Certainly, Moore's Law proved accurate from 1975, when the co-founder of Intel, Gordon Moore (the 'Moore' in Moore's Law), adjusted his earlier observational time frame from doubling every year to every two years, until around 2010, when there were the first signs that the wheels might be coming off one of the most remarkable runs in engineering and economic history.

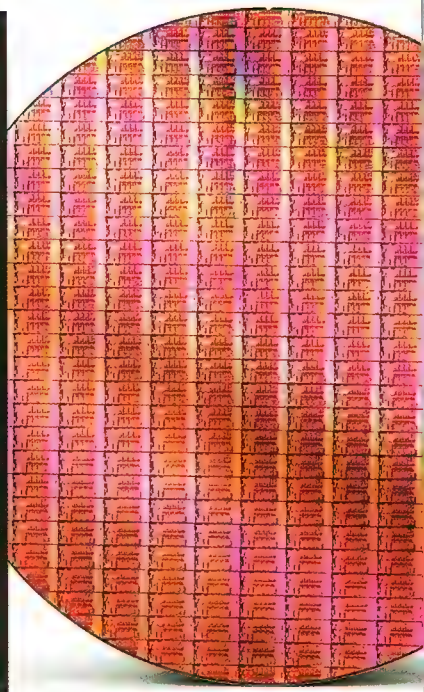
To illustrate that with some numbers, way back in 1970, Intel's first microprocessor, the 4004, packed 2,250 transistors, which was impressive for the day. Intel's latest desktop chip, Alder Lake, contains over 20 billion transistors. Of course, you'd expect today's CPUs to be dramatically more complex than that 50-year-old processor, so try this for a more recent and arguably more brain-bending comparison. The Intel 486 CPU of 1990 boasted 1.2 million transistors. Roughly speaking, that means 20,000 486s would fit inside the die space of a current Intel Core i9-12900K, were the 486 built on the same 10nm production node as the new chip. That's a staggering notion for anyone who can remember a 486 when it was the latest and greatest desktop powerhouse.

Or how about the first "Willamette" Pentium 4, from 10 years after the 486? That was a 42 million transistor chip. Using the same rationale, you're looking at around 500 of those to rack up the same transistor count as a 12900K. Even a fairly modern Core i7 processor from 2010 would fit inside an Alder Lake die 30 times over, again if it were produced on Intel's latest node.

Moreover, do the math on those 10-year transitions and

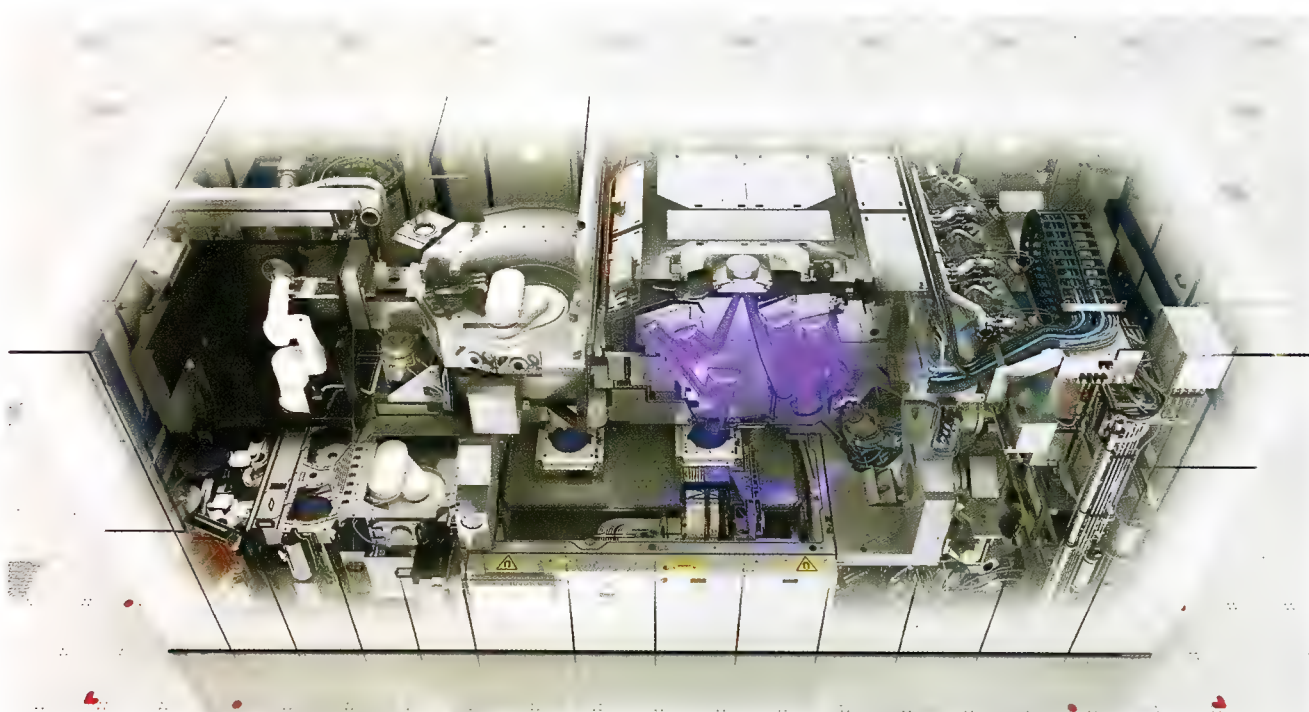


Apple's M1 Max chip packs around 57 billion transistors.



you'll see that they mostly line up with Moore's Law. From 1.2 million in 1990 to 42 million in 2000 is nearly bang-on doubling every two years. From 2000 to 2010 and 42 million to 774 million, there's a little slippage evident. As for the 10 years from 2010 to 2020 (or 2021, at least, with the arrival of Alder Lake), the step up from 774 million to 22 billion is, again, pretty much in line with the expectations set by Moore's Law.

Of course, you could cherry-pick examples that wouldn't fit quite so nicely. Likewise, Intel is just one company, not the entire semiconductor industry. The new Apple M1 Max chip, as found in its latest MacBook Pro computers, packs a slightly crazy 57 billion transistors, for instance. But for as long as we can remember, Intel has been the bellwether for



EUV lithography should keep Moore's Law going for a few more years.



Left: Intel now knocks out 10nm wafers with desktop CPU dies.

Above: ASML's lithography machines are now worth more than Intel's CPUs.

the industry. It's also the outfit that has suffered the most well-publicised chip-production woes of late.

Back in 2015, Intel confirmed that the cadence of Moore's Law, as far as it was concerned, had slowed to two and a half years with the transition from 22nm silicon chip production to 14nm. But it was the jump from 14nm to its latest 10nm node that has proved the most problematic. To understand just how wrong it has gone for Intel, you have to look a little further back in time. In 2012, Intel was expecting to have 10nm processors in production by 2015, with 7nm coming online in 2017 and an even smaller node available in 2019.

But here we are in 2022 with Intel's first 10nm desktop processor having gone on sale just a few months ago. Intel's 10nm is at least five years late. You can read all about what went wrong with Intel 10nm in the boxout on page 64, but suffice to say that 7nm is also proving problematic and is subject to delays. Indeed, the situation has gotten bad enough that Intel has felt the need to rebrand its production nodes to compensate for a perceived lag versus the competition.

To cut a long story short, Intel is now calling its 10nm node 'Intel 7', while the upcoming 7nm node is rebranded 'Intel 4'. If that seems like a desperate attempt to use alternative facts to cover up a technological shortcoming, perhaps there's some truth to that. However, node nomenclature such as '10nm' and '7nm' has long become disconnected from the size of any actual features inside a chip. The gate pitch of most existing production nodes marketed as 7nm is roughly 50nm, for example. So, node names are more a rough guide to comparative density than indicative of actual feature sizes.

On that note, Intel's 10nm tech (the one now known as Intel 7) is said to be good for around 106 million transistors per square millimeter of semiconductor. That's actually slightly better than the 95 million and 97 million achieved by Samsung and TSMC's 7nm nodes, respectively. So, in comparative terms, 'Intel 7' certainly makes sense. That said, both Samsung and TSMC are already producing chips on 5nm processes. TSMC's 5nm node packs in an incredible 173 million transistors per square millimeter, which is what makes that crazy 57 billion transistor count viable for the Apple M1 Max chip in a portable MacBook Pro computer.

MOORE IS NO LONGER LESS SMALLER TRANSISTORS COST BIG MONEY

If the demise of Moore's Law has been called a little prematurely, one thing's for sure: keeping it going is becoming increasingly costly. For instance, Intel says it plans to spend \$27 billion on a pair of 7nm fabrication units, colloquially known as fabs. Meanwhile, just one of TSMC's latest 5nm manufacturing plants, known as fab 18, is said to have cost \$30 billion. That's big money.

Those huge costs are the major reason why the industry is consolidating down to just a few major players. The price of entering the game, let alone of maintaining some competitiveness, is incredibly prohibitive. Another intriguing indicator of just how resource-intensive chip manufacturing has become can be found in the example of ASML (Advanced Semiconductor Materials Lithography). A Dutch company founded in 1984, it specialises in the photolithography machines used by all the big players in chip production. If you want to knock out semiconductors using the latest EUV processes, you need an ASML machine.

But here's the incredible bit. ASML's role is so important, its market capitalisation or overall value is now greater than Intel's. So, the broader economics of chip manufacturing is changing fast – and not for the better. Taking TSMC as an example (it's harder to make these judgments based on Intel because, until recently, it has only produced chips for itself and not acted as a foundry for third parties), consider its transition from 65nm to 28nm. The cost of a wafer went up from around \$2,700 for 65nm to \$4,000 for 28nm. However, because so many more chips can be produced on a 28nm wafer than an equivalent 65nm wafer, the price of individual chips dropped by two-thirds.

However, if you take TSMC's more recent progression from 10nm to 7nm and then 5nm, wafer prices have ballooned from \$8,000 to \$23,000. The consequence is that chip prices have only shrunk by about 15 percent. The moral of the story is that if wafer prices keep going up, it won't matter whether it's technically possible to keep Moore's Law alive. Nobody will be able to afford the chips, anyway.

INTEL'S 10NM NIGHTMARE WHAT WENT WRONG WITH INTEL'S LATEST NODE?

As far back as July 2015, Intel publicly confirmed that its 10nm node was in trouble. Fast forward nearly seven years and we've only just got our hands on its first desktop 10nm processors. Moore's Law dictates a doubling of transistor densities every two years, implying a new process node on roughly the same cadence. So something has gone horribly wrong. But what, exactly?

The first problem was ambition. Intel simply went for too big a leap with 10nm. In 2009, for instance, Intel made the jump from 45nm to 32nm. With that came an increase in transistor density from 3.3 million per square millimeter to 7.5 million, a little over double the density. When 22nm arrived in 2011, it was a similar story. It upped the transistor density ante to 15.3 million, or slightly less than double.

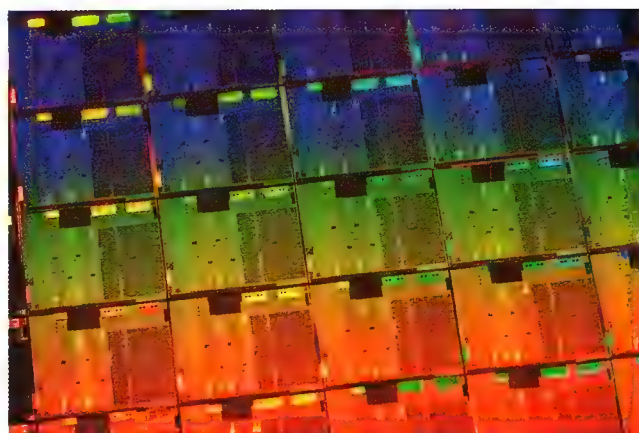
Fast forward to 2014, one year later than you'd expect a new node from Intel, and 14nm delivered 37.5 million transistors per square millimeter. That's well over double what 22nm delivered. 14nm was the first troubled node from Intel, and it's likely no coincidence that it also attempted to more than double transistor density.

Then there's 10nm. The first version of 10nm, which was used in tiny numbers to produce a dual-core mobile chip that almost nobody bought in late 2018, was good for a massive 100.8 million transistors per square mm. That's a huge 2.7x scaling compared to 14nm and a big ask indeed.

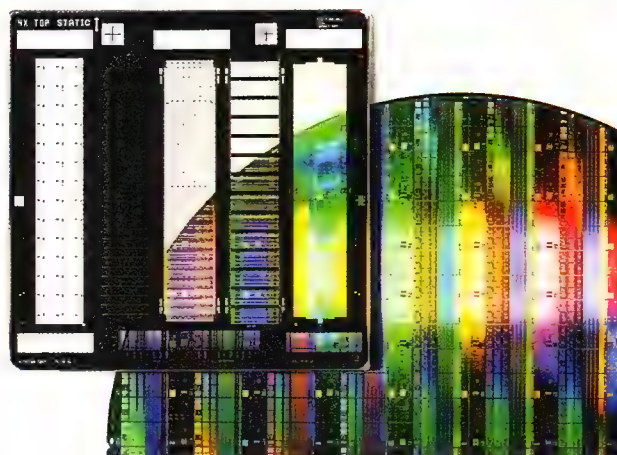
The other problem was that Intel opted not to go with EUV or extreme ultraviolet lithography technology. As we've explained elsewhere, the wavelength of light used in a lithography process ultimately dictates feature size. And, currently, EUV tech is the shortest wavelength and most advanced available for commercial production.

The reasons why Intel didn't go with EUV are quite technical and are related to the fact that it tends to produce chips using single-die masks. Any damage to that mask threatens to kill the entire wafer. By contrast, the likes of TSMC and Samsung tend to use multi-die masks that can sustain some damage while maintaining reasonable yields. Also, EUV-compatible tools to protect masks, known as pellicles, only became available in 2019.

In short, Intel decided not to go with EUV, making that ambitious 2.7x density scaling even more technically challenging. Intriguingly, Intel's next node, formally known as 7nm and now branded Intel 4, is expected to be less ambitious in 'only' increasing transistor density to 180 million per square millimeter, less than double that of its existing 10nm node. It will also be the first Intel node to use EUV technology.



Intel's 10nm node arrived at least five years late.



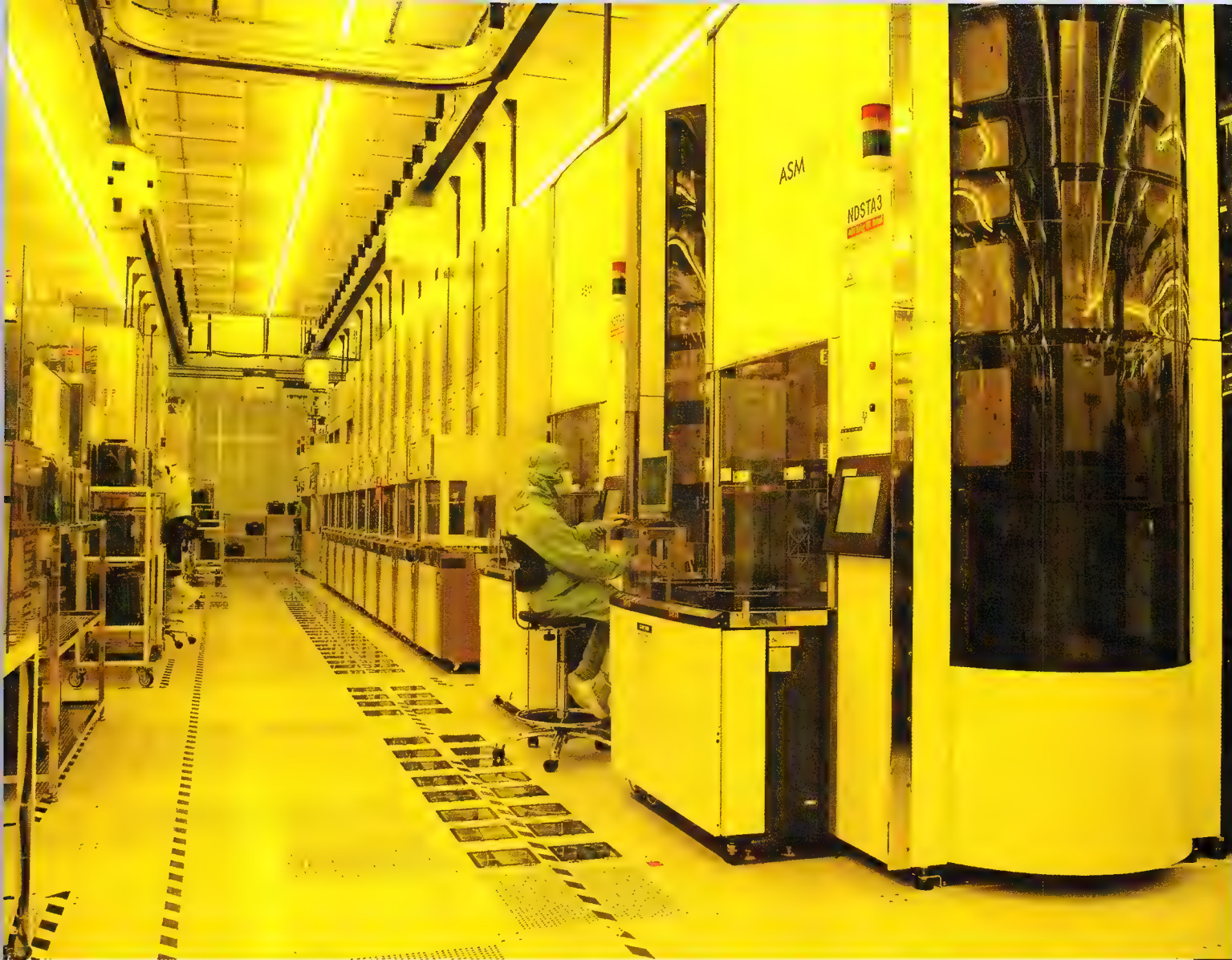
Tools such as masks are critical to the chip production process.

Indeed, if there's a single outfit remaining in the chip industry that best represents the notion that Moore's Law is alive and well, it's surely Taiwan Semiconductor Manufacturing Company (TSMC). It's currently the largest chip foundry in the world and the undisputed leader when it comes to squeezing ever-smaller features into viable, commercial semiconductors that go into products you can actually buy. While Intel has fallen from its leadership position, TSMC has kept on trucking. In September 2020, Apple's A14 chip debuted TSMC's 5nm process, putting it at least a full node ahead of Intel.

Moreover, TSMC is incredibly bullish about its ability to keep Moore's Law going. Philip Wong, vice president of corporate research at TSMC doesn't just think Moore's Law is alive and well, he reckons it could keep on delivering for another three decades. "It's not dead," Wong says of Moore's Law, "it's not slowing down. It's not even sick."

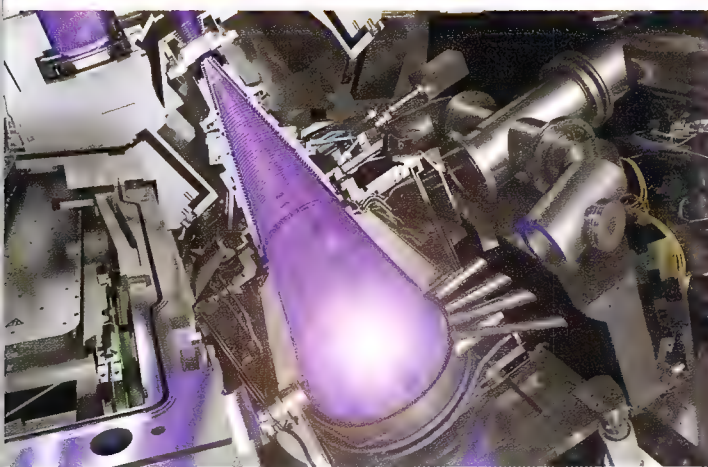
As for how TSMC has achieved its lead, a major factor has been its aggressive adoption of so-called EUV or extreme ultraviolet lithography technology. In simple terms, semiconductor manufacturing comes down to etching details on silicon wafers by shining light through patterned masks onto a substrate. The substrate (or wafer) is coated with a light-sensitive photoresist chemical that hardens when exposed to ultraviolet light, while the remainder of the coating is removed by solvents, leaving a finished circuit.

To a large extent, the minimum size of the features being etched, and therefore the number of transistors that can be crammed into a given area of the wafer, are dictated by the wavelength of the light. The shorter the



Above: TSMC has been making 5nm chips for over 18 months.

Left: TSMC beat Intel to EUV lithography, which is part of the reason why it has a clear node advantage.



wavelength used, the smaller the features. In simple terms, the smallest current production processes demand EUV technology and TSMC absolutely dominates in its use of EUV. Last year, TSMC shipped nearly three-quarters of all semiconductors produced via EUV lithography, Samsung a little under a quarter, while Intel barely factored.

As for overall advanced node capacity, in 2021 TSMC was tooled up for nearly 150,000 7nm-class wafers per month and over 100,000 5nm class wafers. Intel's 10nm node or Intel 7 capacity was around 50,000 wafers.

What's more, late last year TSMC reportedly began trial production of its next major advance, 3nm, with full-scale production slated for the second half of this year. Next year, TSMC is expected to have a staggering 120,000 wafer-per-month 3nm capacity. That 3nm node,

incidentally, is expected to offer a transistor density of 300 million per square millimeter.

Meanwhile, Intel's 7nm capacity (the node now branded Intel 4) is expected to be just 20,000 wafers per month. No wonder Intel has decided to outsource some of its cutting-edge chips to TSMC for manufacture over the next few years while it gets its own foundries in order.

If that's the good news, the bad is that the eventual physical limitation to the existing basis of Moore's Law remains. There's only so far you can go shrinking transistors and other features using conventional semiconductor tech. TSMC's Wong has pointed out that its current FinFET transistor technology is already approaching the atom scale.

"The fin is about 10nm, or rather slightly less than 10nm," Wong says, "and, if you use an extremely high-resolution transmission electron microscope, you can actually see the individual atoms. You can count them. You still need both hands and maybe toes to count the number of atoms in a fin, but not much more than that."

"So, if you go by two-dimensional device scaling by itself – which is a really powerful knob that we have in making new transistors, in providing you density – you quickly see that we're down to very few atoms, and very soon you'll run out of atoms."

On the other hand, this powerful knob that we have been using is not the only knob we have at our disposal."

It's debatable how many more nodes are available using the conventional 2D planar approach. Certainly, TSMC expects to have 3nm and then 2nm conventional planar

THE QUANTUM CONUNDRUM WHAT AN ENTANGLED MESS WE WEAVE...

Forget material science, feature density, and all that old-fashioned stuff involving classical physics and chemistry. Could quantum computing make Moore's Law completely redundant, but in a good way?

According to quantum computing advocates, it's possible to imagine a single quantum computer capable of not just matching the combined number-crunching might of all existing classical computers, but also of executing as many calculations at once as is practically useful. In other words, all the computing power any of us could ever need in a single machine. Forget Bill Gates' apocryphal claim that nobody needs more than 640K, quantum computing aficionados think we won't need more than one PC between the lot of us.

If that sounds like a fringe theory, try this comment from Android OS architect Andy Rubin. "If you have computing as powerful as this could be, you might only need one [computer]." So, how might that work? Conventional computing operates in the binary realm of zeros and ones, otherwise known as bits in computing vernacular. The basic component in a classical computer, the transistor, is therefore either off or on. There is no alternative.

With quantum computing? Not so much. Thanks to a quantum phenomenon known as superposition, which applies at the atomic and sub-atomic scale, it's possible for a quantum computing bit to be not just both on and off at the same time, but also a huge array of hybrid superpositions somewhere in between on and off. This is a qubit and it is the basic building block of quantum computing.

The other important weirdness of quantum computing, and arguably the factor that makes things exciting, is entanglement. It's a notion even tenured physics professors struggle with. But the basics involve the idea that the quantum properties of two or more particles can be inextricably linked regardless of any distance between them. Change the spin of one particle, for example, and others instantly react.

The trick to achieving powerful quantum computing, therefore, is to 'entangle' multiple qubits. Quantum-mechanically link or entangle two qubits and you can perform two calculations simultaneously. Link three qubits and the math of quantum entanglement means you can do two to the power of three – or eight – calculations. Link four and you can perform 16 calculations simultaneously. Follow that logic and by the time you have 300 entangled qubits, you can perform more calculations in parallel than there are atoms in the known universe. Handy.

The catch? There is doubt that a quantum computer on that scale is possible due to the problem of quantum decoherence. Some argue the quantum state of the machine can't be maintained long enough to do anything useful, but others question whether quantum computers can be applied to general computation at all, and instead will always be limited to irrelevant, esoteric math of little practical benefit. Unfortunately, we forgot to polish up on our applied physics PhDs here on *APC*, so all we can say is time will tell.



Are quantum computers, such as the D-Wave Advantage, useful?

semiconductor nodes. Last year, TSMC said that the development of its 2nm is "progressing nicely through the pipeline." 1nm may also be possible using a new approach that replaces FinFET transistors with so-called GAA or Gate All Around alternatives.

But all that begs the question of what those additional 'knobs' Wong was referring to could be? Planar semiconductors are fast approaching their physical limits and can't possibly keep on delivering nearly long enough to fulfill TSMC's 30-year vision for Moore's Law. So, what other types of technologies is the industry likely to turn to?

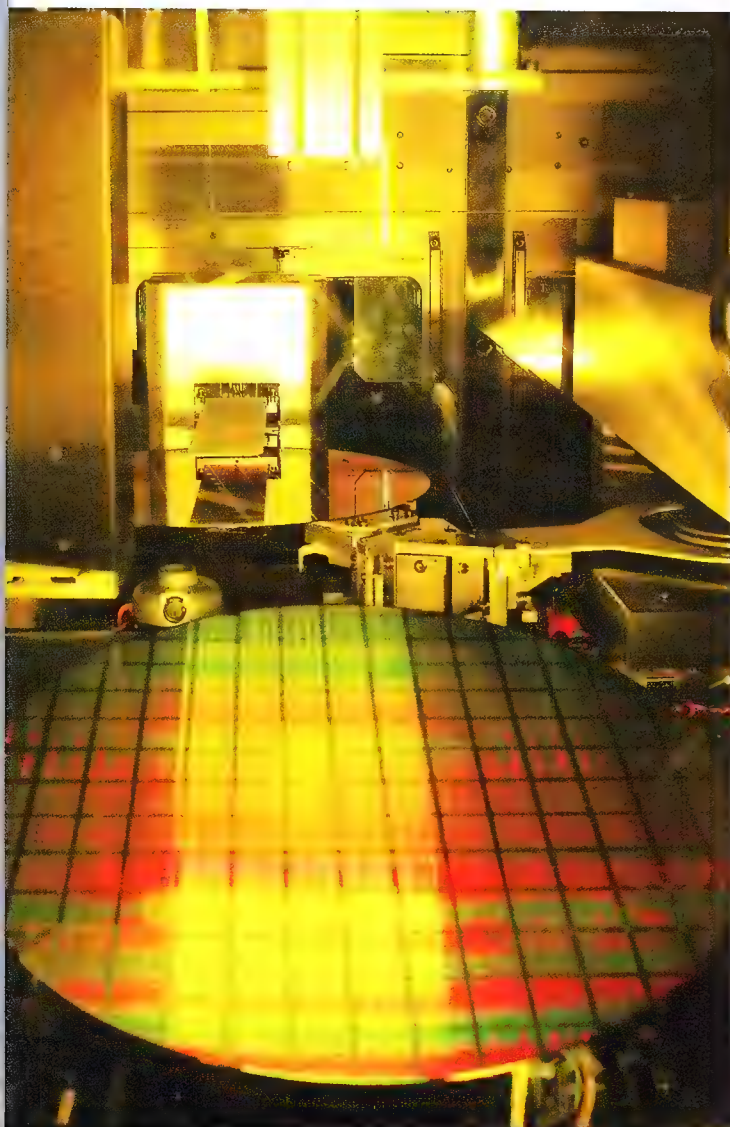
In practice, it looks likely to be a mix of the exotic and the prosaic. If Moore's Law is all about density, taking a slightly different system-level view of that metric allows new chip-packaging techniques to keep the show on the road. Fusing multiple chiplets of both logic and memory together using silicon interposers allows for much greater system density while allowing for better production yields.

Trying to manufacture a single large chip is much harder and more expensive than lots of little chips. But fusing them together in a way that reduces latency and allows for performance akin to a monolithic chip is a huge technical challenge that the likes of TSMC and Intel have only recently begun.

If that's an extension of the existing planar model, the other obvious option is to go up instead of sideways. According to Godfrey Cheng, Head of Global Marketing at TSMC, "one possible path forward is the use of transistors made of two-dimensional materials instead of silicon as the channel. We are raiding the periodic table.

"By potentially using these new materials, one possible future of great density improvements is to allow the stacking of multiple layers of transistors in something we call Monolithic 3D Integrated Circuits. You could add a CPU on top of a GPU on top of an AI Edge engine with layers of memory in between. Moore's Law is not dead. There are many different paths to continue to increase density."

As for the more exotic possibilities, one of the most exciting involves carbon nanotubes or CNTs for short. Composed of tubes of one-atom-thick graphene, they're excellent semiconductors and



AMD could start shipping Ryzen 7000 series CPUs later this year.

have the potential to scale feature densities beyond silicon semiconductors. One of the most significant advantages of CNT-based field-effect transistors, or CNFETs, is efficiency. They are believed to be fully an order of magnitude more efficient than their silicon-based equivalents.

That's a huge advantage, given that power consumption, leakage, and heat are becoming ever-greater problems in existing chips. It also opens the door to much more complex 3D chips than are possible with silicon semiconductors. While stacking multiple layers of silicon transistors is technically possible, doing that within reasonable power and thermal limits is a different matter altogether.

By way of example, Intel's latest Alder Lake CPUs have been measured spiking to over 300 watts. Imagine multiple layers of transistors with that kind of thirst. However, if each layer only consumed one-tenth of that power, then you've got something interesting. There's a snag, of course. CNT semiconductors are incredibly hard to manufacture. However, in 2019 engineers at MIT managed to create a 16-bit processor composed of 14,000 CNT transistors capable of executing actual code. The feature size was relatively large with a gate length of 130nm and a fair way behind the density of existing silicon semiconductors.

It's still early days for CNT technology. Only six years ago, the best anyone had managed was 178 CNFETs in a single chip. Extrapolate that scaling and it won't be long before Moore's Law's two-year density doubling cadence looks pedestrian in comparison. It's optimistic to think that Moore's Law isn't just alive, but set to accelerate. But the possibility speaks to the fact that it's all to play for. You could say there's Moore to come.

COULD WETWARE WIN? NEURONS VERSUS TRANSISTORS: BUT WHICH IS BETTER?

Is there something special about the human mind that gives it an inherent advantage over any conventional, binary computer? In simple numerical terms, brains are still far superior. Composed of something like 100 billion neurons, there's complexity beyond any existing computer chip, even before you acknowledge that neurons are far more complex than binary transistors.

It's thought each neuron can be connected to as many as 10,000 other neurons, the net result of which is up to 1,000 trillion synaptic connections. Try simulating that on a mining cluster of RTX 3090 GPUs. Of course, the brain's detailed functionality isn't something that can be easily reduced to numbers. But it's still remarkable to think about all that power and connectivity, and still consider that the brain's power consumption tops out at about 20 watts. How do you like them apples, Intel mobile CPU?

While we can debate the true computing power of biological brains, there's little doubt we can learn a lot from them in terms of efficiency. As for other learnings, biology obviously informs the disciplines of machine learning and AI. That alone may be enough to create new software paradigms that accelerate effective computing power in a way that keeps the implied impact of Moore's Law – an exponential growth in computing power – alive.

A parallel pursuit in this field is biological computers, or computers built from living cells. Yes, it's been happening for years. In 2016, researchers from MIT created a machine based on cells that can perform simple computational operations, as well as store and recall data. It's early days for this area of research and there's no telling where it will lead. But it's not impossible that biological computers could step in just when more conventional efforts involving silicon or carbon nanotubes reach their physical limits. ■

PASSWORD

TPM EXPOSED

WHAT EXACTLY IS THAT MYSTERIOUS LITTLE CHIP THAT'S APPARENTLY SO VITAL TO WINDOWS 11? **DARIEN GRAHAM-SMITH** DELVES INTO THE SECURE SPACE.

Buy a Windows computer today and it's all but certain to contain a TPM. That's a Trusted Platform Module – an unassuming component that performs a standard set of security functions. Those are defined by the Trusted Computing Group, an industry body with more than 100 members, including AMD, Dell, Google, Intel, Lenovo and Microsoft, working together to improve security across computing devices and applications.

The group has been around in various forms since 1999, but it was in 2009 that it published the first TPM standard (curiously presented as version 1.2). This was quickly adopted across the industry, thanks partly to support built into Windows Vista. In 2015, the TPM 2.0 standard brought extra features, and remains the state of the art for trusted computing.

Despite its ubiquity, the TPM has always been an optional component. It's been up to computer manufacturers whether to include one in their designs, and up to users whether they want to enable or disable it in their BIOS settings. With Windows 11 however, the mood has changed: Microsoft has declared that the

latest edition of its operating system will only be supported on systems where TPM 2.0 is present and enabled.

That's a controversial decision. Windows 10 didn't require a TPM, and it's possible to use Windows 11 without one. Microsoft even provides a hack that lets you install its latest OS without a TPM – see pcpro.link/331tpmhack. If you take this route, however, your PC will be classed as unsupported, meaning it's not guaranteed to receive future updates.

So why has Microsoft decided to make TPM 2.0 a requirement? To understand, we must examine exactly what a TPM is and what it does.

Where is the TPM?

The Trusted Platform Module was originally conceived as a small, low-cost chip that could be plugged into a dedicated socket on a motherboard. As TPM support became the norm, manufacturers started soldering the chip directly onto the board itself.

The specification doesn't require that the TPM be implemented as a physical chip, however. In fact, these days the full set of TPM functions can be integrated into the CPU firmware – as is the case

with every processor on the Windows 11 supported hardware list, from both AMD and Intel.

If the Windows 11 installer says you don't have a TPM, therefore, it might be that the feature simply needs enabling in your BIOS. If you can't find an option to turn it on, you might need to look for a different name: AMD's integrated TPM system is called the Firmware Trusted Platform Module (fTPM), while Intel's is called Platform Trust Technology (PTT).

What does the TPM do?

The TPM works like a miniature computer. It receives commands, returns responses, and can also store and regurgitate information. To enable it to do this, it has its own onboard storage: the specification requires that a TPM must have at least 7KB of storage, but newer modules can have upwards of 100KB. All of this memory is non-volatile, meaning it retains its contents when unpowered, like an SSD.

Of course, if you just want to store and retrieve data you might as well use the hard disk. What makes the TPM special is that data can have conditions attached to it, governing how it can be accessed. For example, when an application

entrusts a password in the TPM, it can mark it as only accessible to the same process that originally stored it. If any other program requests the information – such as a piece of malware – the TPM will refuse to provide it. Since the TPM is completely separate to and outside of Windows, the malware is stymied.

A TPM can equally deny or allow a data request depending on the state of the computer. This is because the TPM has the ability to audit the hardware configuration of the computer it's installed in, and to log the software that launches on it. It can then determine whether or not it's in a known, trusted environment, and respond accordingly.

If you enable a power-on password for your PC, the TPM can help here too, by validating the credentials against the details stored in its memory. That prevents a thief from getting around the password by clearing the BIOS.

There are even built-in protections against “brute-force” attempts to guess the password: after a few wrong entries, the TPM will make you wait an increasingly long time until you can try another. Too many wrong guesses result in an enforced delay of 24 hours – and don't try to change the date in the BIOS or whip out the CMOS battery, as the TPM has its own clock.

This is all good stuff: the TPM can help prevent thieves and intruders from accessing protected systems, and block malware from exfiltrating sensitive data. But we haven't yet come onto perhaps the most important function of a TPM.

Cryptographic magic

The TPM can store data as-is, but it can also perform cryptographic functions on it. Specifically, it can apply public-key cryptography, which involves a pair of encryption keys, one of which you keep secret while the other is shared far and wide. Anyone can use your public key to encode a message to you, but only your private key can decode it. Or, your private key can be used to generate a cryptographic hash of a message or file in a way that can be validated using your public key, proving it was “signed” by you and hasn't been tampered with.

Thus, once you've stored your private key in the TPM, it can encrypt files, decrypt files and generate signatures for you – but if

the system isn't in an approved state, or if the request comes from an unfamiliar process, the TPM can simply refuse to cooperate. There's no need to export the key back to the operating system where it could potentially be spied upon – in fact, it's possible to lock down the key completely, so that it can never be extracted.

This means the only real window of opportunity for someone to steal your key is at the point when it's generated and loaded into the TPM in the first place. Even that tiny loophole is easy to close off, because every TPM can generate its own internal keys, which can then be used for encryption-based tasks without ever being seen by the operating system or firmware. If you want to pass a computer on, you can simply send an instruction to the TPM to reset its key storage, and those keys will be gone forever.

This raises an obvious question: how do you move between computers without losing access to your secure keys? The answer is that, as well as placing restrictions on how data in the TPM can be accessed, you can also control whether and how it can be migrated from one TPM to another, with restrictions such as requiring a password or a specific system state.

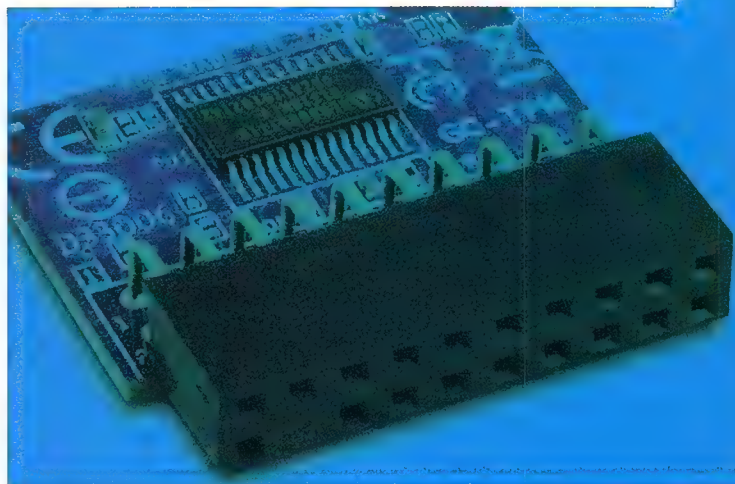
How Windows uses the TPM

Any application that uses encryption can get a security boost by using a TPM, rather than storing its keys in system memory or on disk. Windows makes this easy with an OS component called the Platform Crypto Provider, which provides TPM-based cryptography services without developers needing to delve into the workings of the module itself. It can also act as a gatekeeper for the TPM: when the Crypto Provider tells the TPM only to allow specific processes to make use of certain keys, other processes (such as malware) are completely shut out.

Probably the best-known popular application of cryptography in Windows is BitLocker, which provides full-disk encryption. To be accurate, BitLocker encrypts your whole disk except for Windows Boot Manager, which launches as usual when you

power on the PC. When it sees that the system disk is encrypted, this program then requests the decryption key from the TPM, which recognises the Boot Manager as a trusted process and provides it. This key is used to unlock the Windows startup files, along with all the other data that's stored on the drive, allowing the computer to boot.

On its own this might sound rather pointless, since the drive is decrypted and booted automatically. However, it means that the only way to access the computer is by starting Windows – so if you don't have the right password, you're locked out. If you try to access the hard disk from a different OS, or using different hardware, all you'll see is unreadable encrypted data. The TPM can also refuse to provide the



Above: Like a mini computer, the TPM receives commands and stores data.

key if it detects a change to the Boot Manager code or to the hardware environment, shutting off the opportunity for malware to infect your startup code.

In general, it's a good thing that BitLocker uses the TPM to lock away its cryptographic key. However, it raises the significant question of what happens if, for example, the host PC dies, and you need to move the hard disk into a new system to keep working. Microsoft has thought of this: when a drive is encrypted, BitLocker generates a 48-character recovery password, which can be used to decrypt an entire drive. For obvious reasons, though, this can't be safely stored on the drive itself. In an enterprise scenario it will be recorded in Active Directory Domain Services, where it can only be accessed by network administrators, while for individuals it's stored in your

Microsoft account and can be found via the Microsoft website.

On that note, it's worth clearing up a point of confusion. BitLocker is only available in the Pro and Enterprise editions of Windows 10 and 11, but that doesn't mean the Home editions can't enjoy similar protections. Home users can turn on a feature called Device Encryption, which does almost exactly the same things as BitLocker: the biggest difference is that it's much less finicky about changes to the hardware and software environment, and will normally let you boot as long as the TPM is present and correct.

Aside from BitLocker, the TPM also helps power a few behind-the-scenes security features. In the Enterprise and Education editions of Windows, a technology called Device Guard can be used to run

we've described so far is fully covered by the original 1.2 specification.

What TPM 2.0 does bring is a few technology upgrades. The original TPM specification used the popular RSA encryption algorithm, but the newer version also supports stronger elliptic-curve cryptography. It can also generate 256-bit SHA-2 hashes, which are far harder to crack than the 160-bit SHA-1 ones supported by the original TPM standard. It makes sense that Microsoft would want to standardise on the most secure TPM version available.

There's another possible reason why Microsoft has chosen to insist on TPM 2.0: it requires a UEFI BIOS, which the company has long recommended as the best choice for Windows. As well as allowing some BIOS functions to be

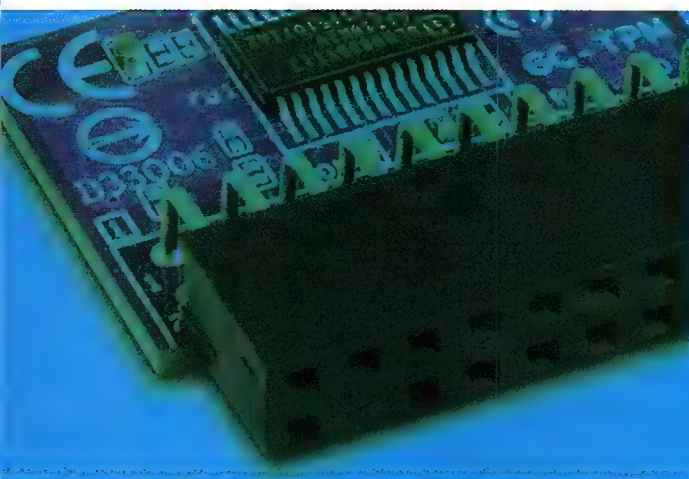
concept relies at least partly on the stability and trustworthiness of the operating system that interfaces with it, but that can't be taken for granted. We haven't yet heard of an exploit that hijacks Windows to compromise access to the TPM, but it's impossible to guarantee one won't ever be found.

It's also important to realise that TPM techniques can't defeat all types of attack. They're powerless to protect against keyloggers that monitor the hardware as you're typing in a password, or phishing attempts that invite you to enter your credentials into a nefarious website. This may be why Apple has chosen not to join the Trusted Computing Group, instead developing its own T2 security chip, which not only handles credentials such as fingerprint and password data but can control the microphone, camera and other sensitive hardware.

Then there are concerns about the potential of TPM technology to prevent users doing what they want on their own computers. For example, an operating system could use the TPM to remotely verify an application with the publisher, and refuse to open it if it doesn't match an approved signature. Worse, that approval could be rescinded at any point – such as when the publisher stops supporting it, or goes out of business – leaving you unable to use your installed software.

That complaint was common in the early days of trusted computing – the media referred to the TPM as a “DRM chip”, and free software evangelist Richard Stallman derided it as “treacherous computing”. Those issues are rarely brought up today, though – perhaps because it's become apparent that such restrictions are more likely to be implemented via cloud-based software subscriptions rather than through the TPM.

This isn't the place to get into that debate, however. What we can say is that, so far, the rise of the TPM has toughened up security without bringing about the Big Brother-esque consequences that some feared. It might be frustrating to see Microsoft cut off so many computers from its latest operating system, but we can't entirely criticise the company for establishing a new security baseline, and helping to ensure that the coming generation of personal computers are as secure as they can be. ■



It's important to realise that TPM techniques can't defeat all types of attack

applications in a secure virtual environment, from which they can't access the system software, while Credential Guard stores sensitive data such as password hashes and stored credentials in a virtual machine that's inaccessible to processes running in the normal operating system space.

Elsewhere, Windows' networking services can use the TPM to confirm that a computer trying to connect to a server is the same one as was originally registered and check whether it's using BitLocker and other security features – adding an extra level of reassurance to everyday security as well as remote support and administration.

What's new in TPM 2.0?

Windows 11 doesn't just require a TPM: it specifically calls for version 2.0. The difference isn't enormous, however. Everything

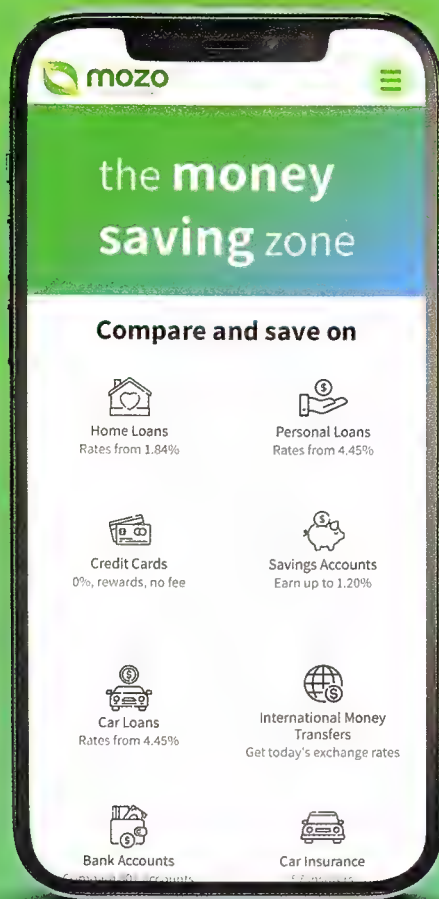
integrated into Windows, UEFI supports the Secure Boot option, which will refuse to load an operating system that doesn't match a recognised hash. This ensures that if any rootkit-type malware tampers with the Windows startup routine, the boot process will fail and you'll know something is amiss. Secure Boot doesn't use the TPM, but it ties in with the same desire to improve security at the most fundamental level.

Problems with the TPM

The most common complaint about Windows 11's hardware requirements is that they're unnecessary: for everyday use, the new OS works perfectly well on older hardware. However, there are some who take issue with the very idea of the TPM.

One objection is that it fosters a false sense of security. The TPM

Above: Once a chip, a TPM's functions are now integrated into CPU firmware.



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NFTS:

WHAT'S THE POINT?

THERE'S AN NFT GOLDRUSH GOING ON. SHOULD YOU GET INVOLVED OR LEAVE WELL ALONE? **JAMES O'MALLEY** INVESTIGATES.

One of the best features of the internet is that nothing is scarce. If I were to lend you a CD, I would no longer be able to listen to it, but if I send you an MP3, we can both enjoy the music. Similarly, there's never any risk of the newsstand running out of newspapers, as the sharing of information has been liberated from the physical constraints of newsprint.

Every bit and every byte can be copied, duplicated and shared with relative ease, and this is a very useful thing. So, it's odd that arguably the most talked about new technology today is designed to make digital goods scarce again.

NFTs, or non-fungible tokens, are digital certificates of authenticity. They use complex mathematics to prove beyond any doubt that you – and only you – own whatever it is they are attached to. And if NFTs take off, they could transform how digital goods work, and create a world where it's possible to own images, avatars or any other type of digital file, just as we can own things in the real world.

If you've spent any time on the internet lately, you'll know that they are already exploding in popularity. Particularly in the world of digital art, as the web has been taken over by an invasion of cartoon apes, pixelated zombies

and plushie kittens (don't ask).

With thousands of unique variations, each of the thousands of characters has been sold as an NFT by groups of developers and artists, and they have become such status symbols that famous names ranging from Paris Hilton to Jimmy Fallon have all been getting in on the trend. Even Melania Trump, the former First Lady of the United States, has attempted to cash in.

In fact, the NFT market is already extremely valuable. Last year, blockchain analysis firm Chainalysis estimated the entire market to be worth \$56 billion, and 2022 looks set to be another bumper year.

Today, music fans can buy NFTs representing John Lennon's collection of Beatles memorabilia, and gamers can buy NFTs of items in games from Ubisoft. Samsung has even built an NFT marketplace into its most recent line of televisions. NFTs are increasingly everywhere we look.

Despite the attention, not everyone is on board, as opponents have likened the gold rush to a scam or a pyramid scheme, and some buyers have already lost a lot

of money. Is there anything in the NFT world that's worth clinging on to?

Enter the blockchain

The secret ingredient that makes NFTs immutable is the same technology that's undergirds cryptocurrencies: the blockchain.

A blockchain is effectively a database that doesn't need a central server to store its data, nor an administrator to manage it. Instead, its data is "distributed" and held by other blockchain users, who verify each others' transactions using complex mathematics. It's like making a payment to another person, but with a bunch of other people watching, who can vouch that the transaction really did take place.

NFTs build on this principle, but instead of simply recording who sent money where, a digital file – such as a work of art – is attached to the transaction. This effectively creates (or "mints", to use the jargon) a permanent record associating that person with that file; as the blockchain has no owner and cannot be modified, we can trust



Above: Project Cosmos is sending NFTs into space.



that the record is accurate. So, if you want to see who owns a given piece of NFT art, you can look it up on the blockchain.

Using this clever mechanism, NFTs work a little like the art world in real life, but instead of an artist selling numbered limited edition physical prints to art collectors, they sell NFTs digitally signed by the original creator. If you buy one, the transaction is recorded and you have proof that you “own” the art.

Of course, if you really want to, you can just right-click and save whatever digital art you like, in the same way you can find a print of the Mona Lisa in the museum gift shop. However, the art world knows that these copies aren’t authentic; owning an original numbered print or an NFT minted by the original creator is the only true mark of credibility.

An NFT success story

Someone who has seen the appetite for NFTs up close is Andrew King, a lecturer at UK’s Manchester Metropolitan University’s School of Digital Arts. He created a series of NFTs called “Cryptoknitties” – characters that resemble knitted dolls – to see what all the fuss was about. It was a lucrative experiment.

“I had a bunch of artwork that

I’ve been using as test data for a tool that I’ve been developing that creates algorithmically generated characters,” he explained. “I put a tweet out about it and it just went mad. Just people saying, ‘where can we get them? When can we get our hands on these things?’”

Cryptoknitties, much like “Bored Apes” and other NFT characters, take a basic template and then use software to create variations with different combinations of colours and accessories. Sensing an appetite for them, King launched a sale of the character designs as NFTs. “We hyped it up to the max,” he said. “Within the first five minutes, we were hit with 32,000 requests for 10,000 items.”

Demand was so high on the first evening that transactions couldn’t be processed on the blockchain fast enough. After a fortnight, the Cryptoknitties had sold out, netting King close to a million pounds. Now King finds himself as the unexpected leader of a community of around 2,000 Cryptoknitty owners, and is currently working on using the windfall to build a game in which buyers can use the characters they’ve bought.

King’s story is, amazingly, not unique; other creators have found NFTs similarly

Above: NFTs were recently the subject of an exhibition in Moscow.

lucrative. The most well-known example is a group that calls itself the Bored Ape Yacht Club, which is responsible for the almost ubiquitous ape characters that, like Cryptoknitties, have been generated algorithmically to make each design unique. So far, the group has reportedly received over a billion dollars in sales.

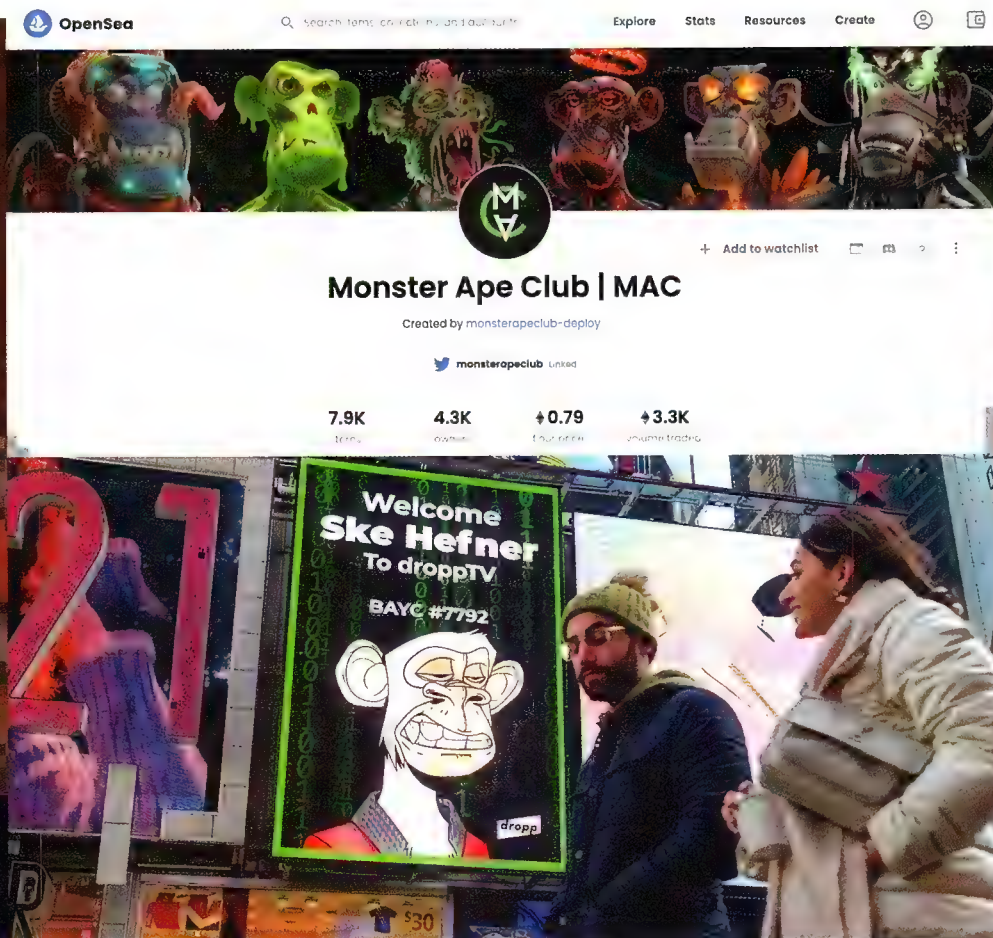
All is not as it seems

NFTs are clearly proving profitable for some people, then, but what about the folk at the bottom of the chain? What are they getting for their money? Critics say: not a lot. “The whole thing is a get-rich-quick scheme,” lamented David Gerard, a crypto analyst and author of *Attack of the 50 Foot Blockchain*. “NFTs are just the latest iteration of the whole marketing thrust of cryptocurrency in general, which is coming up with a form of magic beans and getting people to give you real money for them.”

Needless to say, Gerard is not a fan, and believes that NFTs and crypto more generally are a magnet for fraudsters that could put consumers at risk. “The secondary market doesn’t exist,” he said. “The history of sale of an NFT is typically that these guys trade the NFT among themselves, then

Below: NFT-sceptic Moxie Marlinspike’s NFT appeared as a poo emoji.





someone who's outside that circle buys the NFT, and it never moves again."

There are other signs of problems in the market. For example, OpenSea, the most popular NFT marketplace platform, recently revealed that 80 percent of freely created tokens on its platform were either plagiarised, fake or spam. However, there is arguably a much more significant issue. Even if the NFT market matures and manages to reduce fraud, a structural issue with the design of NFTs is that it still isn't entirely clear what they represent.

Though an NFT is immutable, by virtue of being on the blockchain, most tokens do not actually contain the artwork they are supposed to represent. Minting a large image file to the blockchain would be expensive and time-consuming – it would cost the seller more in transaction fees (or "gas", in the jargon) and take longer to process. Many NFTs add nothing more to the blockchain than a URL of a traditional web page that contains the artwork instead.

This means that instead of putting your name to a work of art that is indelible, what you may actually be buying is a link to a web page that can be very easily modified. On the NFT, there isn't even any form of cryptographic hash that could be used to verify

an image without saving a copy of it. "It's not a picture of an ape," said Gerard. "It's the URL of a picture of an ape that may or may not still be there."

The issue was highlighted by Signal app creator Moxie Marlinspike, a well-known NFT-sceptic, who created an NFT and used some clever code in the image URL to have it display a different image, depending on which NFT marketplace it was being sold on. On OpenSea the image appeared to be a circle made of radiating straight lines; on Rarible it displayed as concentric circles. Once the NFT was viewed in a crypto wallet, it became the poo emoji.

More recently, the ex-footballer John Terry made the point even more starkly. Just days after launching an NFT, which featured a monkey wearing a Chelsea shirt flanked by the Premier League trophy, he was forced to update the image to remove the trophy after the League's lawyers got involved.

Terry's travails also highlight another ambiguity that is as yet unresolved: what rights owning an NFT actually gives you over an artwork. "There was a huge amount of confusion when this first became a mainstream topic of conversation a year ago," said Jon Sharples, an intellectual property specialist at Canvas Art Law, who advises clients on NFTs. According to Sharples, there is no broadly

Top: Apes are ubiquitous in the world of NFTs.
Above: NFTs are even appearing on billboards in city centres.

agreed set of legal rules on what an NFT actually entitles you to do. For example, though you may "own" an NFT of a given artwork, it does not necessarily grant you the legal right to display or reproduce the image.

He points to the Bored Ape Yacht Club as an example. There's a website for the project, and that website contains terms and conditions. As with the images themselves, because the website can be changed, there's no guarantee the terms listed will stay the same.

However, this is an area where Sharples believes that NFT sellers will eventually settle on a fix. "I think it will start to be demanded that the actual account of the rights that you have are attached to the token in some kind of unseverable way," he said, suggesting that one day it may become common to embed the licensing terms in NFTs, so that everyone understands what they are buying.

Why bother?

There is one obvious question left to ask: why? Why might someone want to buy an NFT? If they're just digital tokens that do not grant any actual rights or exclusivity over the content, why is the industry exploding?

"It took me a while to work out why these things triggered any acquisitive desire in anyone,"



HOW MUCH?!

The first NFT was minted in 2014 by entrepreneur Anil Dash, but it was only last year they truly took off. This was in large part thanks to the sale of an artwork by Mike Winkelmann, better known as Beeple.

Everydays: The first 5,000 days is a collage of art and photos taken from each of the 5,000 days of his life, and last March was sold by auction house Christie's for \$69.4 million. The buyer was Vignesh Sundaresan, who is, of course, an NFT entrepreneur.

In fact, the start of 2021 was particularly lucrative for Beeple, as he also sold two of the other most expensive NFTs to date: a piece called *Crossroads* and another called *Ocean Front*, for a paltry \$6.6 million and \$6 million respectively.

Beeple's record sale held until last December, when a mysterious digital artist

called Pak sold an NFT of a work called *The Merge* for \$91.8 million. It depicts three white spheres on a black background. The buyer was not one individual. A consortium took advantage of the structure of NFTs and instead the work was sold to 28,983 buyers, who each bought an NFT representing their share.

Other high-profile sales include a copy of the original "Doge" meme, which features the now famous Shiba Inu dog, which sold for \$4.4 million, and NSA whistleblower Edward Snowden, whose self-portrait of sorts sold for \$5.4 million.

Similarly, Twitter creator Jack Dorsey sold an NFT of his first ever tweet for \$2.9 million. And even World Wide Web creator Tim Berners-Lee has got in on the act, auctioning off an NFT depicting a few lines of source code from his creation for \$5.4 million.

said Sharples, "but then that's also true of other luxury goods that signify status.

"I don't easily understand why people buy Louis Vuitton handbags either. Nor do I understand why my granddad collected silver spoons with enamel handles. But among him and a small group of his mates, that was important. And each of them achieved some level of status among themselves by owning this incredibly esoteric thing, that only they cared about. And it's a similar thing with NFTs."

He likens NFTs and the eye-watering sums of money that are being spent on them to what motivated the buyer of Leonardo Da Vinci's *Salvator Mundi*, which was sold for a record \$450.3 million in 2017 (that's six times the value of the most expensive NFT).

"Access to the object itself is not the whole thing," Sharples explained. "It's just whoever wins this will be known to be the owner of the most expensive painting. And that in itself was a significant element of the sale.

"That's a very long-winded way of saying none of it is rational."

Owning an NFT can act as a status symbol in certain online communities. And the community aspect can be important, too. "The community is a huge driver for Cryptoknities," said King, "Our Discord server is very active, and the community makes active



contributions to the project. They buy into it to contribute to the ecosystem and allow us to keep on developing and that kind of thing."

King says that his goal for Cryptoknities is to use the money raised to finish the game, making the act of buying an NFT a little like contributing to a Kickstarter project. But, of course, there is one other reason there's an NFT goldrush: the pursuit of cold, hard cash. "There is a significant amount of the market for NFTs who, if we're being brutally honest, are not interested in the NFTs," said King. "What they're interested in is getting it and selling it on.

"With any drop now, you'll probably see at least a third of it on the secondary markets within a

Top: Twitter's Jack Dorsey sold an NFT of his first tweet for \$2.9 million.

Above: The original Doge meme was sold for \$4.4 million.



day or so," he added.

This is why people such as Gerard remain sceptical. "Crypto marketing really leans on obfuscation," he said. "It makes something that sounds really obscure and complicated. And then you get the person to assume good faith in your thing, even though it doesn't make sense."

In any case, it appears that, in the short term at least, NFTs are here to stay. The jury is still out on whether they will transform how we think of digital objects or whether the bubble will pop. So when it comes to NFTs you'll have to decide: is it time to jump in and buy yourself a token of appreciation, or would it be wiser to make yourself scarce instead? ■



UNDER- STANDING IP

NETWORKING TECHNOLOGY
NEEDN'T BE COMPLEX.
DARIEN GRAHAM-SMITH
EXPLORES THE PROTOCOL
THAT UNDERPINS ALMOST
ALL NETWORKS, FROM YOUR
HOME LAN TO THE INTERNET.

When we see a string of numbers such as “192.168.0.1”, most of us know that we’re looking at an IP address. But what exactly is an IP address, and why does it take that form? These are things you might not know – and that’s fine, because you don’t need that level of knowledge to keep your home or small office network running smoothly and securely.

Even so, the information can be useful when it comes to troubleshooting and optimising your network – and it’s interesting, too, in a geeky sort of way. Here’s a quick guide to the mysteries of IP and how it works.



01 What needs an IP address?

The full name of IP is “internet protocol”, but it’s not just used for internet connections. In fact, any device that’s on any sort of network must have an IP address. If it doesn’t have an address, it’s not on a network, because nothing else can talk to it.

To be fair, that’s a simplification. There are numerous networking systems that don’t use IP addresses: in the 1990s and before, many firms ran their networks on Novell NetWare, which used the IPX/SPX protocol; others used the NBF system (also known as NetBEUI) popularised by IBM. Modern technologies such as Bluetooth and Zigbee also allow devices to communicate without using IP. Generally speaking, though, IP has become the universal default for networking, because it’s open, mature and suitable for both local and internet connections.

There also doesn’t have to be a one-to-one correlation between devices and IP addresses. There can’t be two systems with the same address on a network; this would make it impossible to route packets correctly, and may end up

making them both inaccessible. However, one machine can have more than one IP address. Virtual machines often have their own addresses, separate from their host systems. And a single computer will automatically acquire two IP addresses if you enable two network interfaces at once, which you might do for traffic filtering or just so you can access two separate networks simultaneously.

It’s a fair bet, though, that the vast majority of connected devices in your home have one IP address. The exception is your router – but we’ll get to that in a moment.

02 What do the numbers mean?

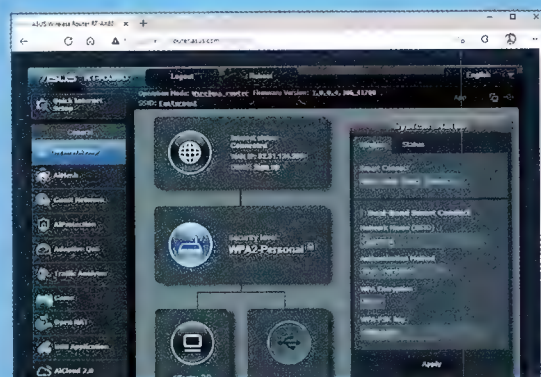
An IP address is normally expressed as a series of four numbers from 0 to 255 (at least it is under the IPv4 standard, which we’re focusing on here). Believe it or not, this convention is intended to make addresses easier for humans to work with: for a computer it’s just a convenient four-byte chunk, or a single 32-bit number.

Since each of the four sections is an eight-bit number, the parts are known as octets. On most home networks, the first three octets

will be the same for every device. The last number uniquely identifies each client; self-evidently this means that you can have up to 255 devices on a single network, minus a few addresses that are reserved for special functions.

If you need more than this, you can create additional subnets. For example, many home networks have addresses in the range 192.168.0.x; if you need more, you can start using 192.168.1.x, and so forth. If you use all available combinations of the third and fourth octets, you get a generous total of 65,025 addresses.

Below: Your ISP gives your router a globally unique address.



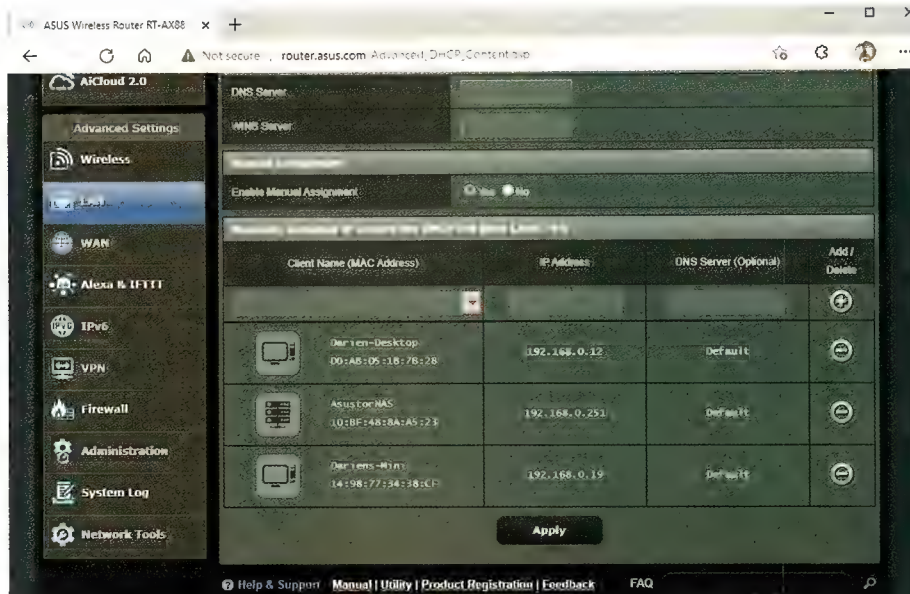
03 Who decides what gets what IP address?

Every device or server that's directly connected to the internet needs to have its own unique IP address. This will normally be assigned by the ISP providing the internet service, which acquires the rights to address ranges from a regional internet registry. At the top of the tree, the Internet Assigned Numbers Authority (IANA) monitors and manages the registries and makes sure that no-one is using addresses they're not entitled to.

However, the individual computers inside a home or office network don't normally have a direct internet connection. They have access to an internet gateway, but their own addresses are internal ones that are only valid inside the local network.

How are these internal addresses determined? When IP-based networking was new, it was common for the network administrator to assign a permanent ("static") IP address to each computer on the network. However, this approach involves a considerable management overhead, and doesn't permit simple "plug and play" connections to the network. Nowadays we use a system called the Dynamic Host Configuration Protocol – DHCP for short – which allows the router (or a dedicated server) to automatically allocate a unique internal IP address to each device as soon as it connects to the network.

Above: You can easily change the DHCP settings on your router.



While this makes life easy, it can create confusion, because DHCP allocations don't last forever. This doesn't mean things will get kicked off your network – if a device is still in use when its address lease expires, it will be quietly given a new one, and normally you won't even know it happened. However, with something like a NAS appliance or printer, you might want to ensure that the IP address never changes, to make certain that all connections and network functions will keep working.

There are two ways of achieving this. One is to configure the IP address manually on the device itself, just as you would have on an old static IP network. Just make sure that your chosen address doesn't clash with anything else on the network; an easy way to do this is to pick an address like

192.168.0.3, then go into the DHCP settings on your router and set the DHCP address range to start at 192.168.0.4.

Alternatively, you can keep whatever IP address was automatically assigned, and tell your router to permanently reserve that address specifically for that device. You can normally do this from the client list in your router's interface, or using a dedicated IP address reservation page. Strictly speaking, the router is associating the IP address with the hardcoded MAC address of the client's network interface, so if you were to take the network card out of one machine and put it into another, the IP address would go with it.

04 What's NAT?

We mentioned above that all the devices on your network use internal addresses that are only valid on the LAN. These addresses aren't picked at random: there are a few address ranges that are reserved for this role, with the 192.168.0.x range being one of the most popular. Thus in my home the address 192.168.0.17 refers to an iPad, but in yours the same address might be used by a smart TV or an Amazon Echo Dot. Since these local addresses are only used inside our respective LANs, there's no possibility of a clash.

The router also has its own internal address (typically 192.168.0.1) – but as part of your home internet service, your ISP also provides your router with a globally unique address. This allows the router to send and receive data to and from other internet hosts, such as websites and online services.

THE DREADED DOUBLE NAT

NAT is a good thing, so double NAT must be better, right? Not really. Double NAT normally happens when you connect a device with router functions to a network that already has a router – for example, you might find that the only way to get a new Wi-Fi 6 router on to the internet is to plug it into your old ISP-provided router.

A double-NAT configuration means that you end up with two devices handing out IP addresses. This isn't a disaster. The secondary router won't assign addresses that clash: if the old router is issuing addresses in the 192.168.0.x range, the new one might use the 192.168.100.x range. And the two routers should be able to pass packets between themselves so that all systems can talk to one another and get on to the internet.

Double NAT can create problems, though. Since the secondary router doesn't have its own external IP address, nothing connected to it can receive incoming connections. UPnP won't help, as the computer running the application isn't directly connected to the router that's connected

to the internet. Similarly, QoS features that aim to prioritise particular clients or traffic types can get confused, since the primary router can't probe devices connected through the secondary one. And while NAT itself doesn't open up any network vulnerabilities, it does mean you need to stay on top of security settings and patches for two routers instead of one.

There are a few possible solutions. Many routers and mesh systems offer a bridge mode, which effectively turns them into network extenders for the primary network: this lets you use their wireless capabilities, but advanced features such as parental controls or network security scanners are normally disabled.

Alternatively, you can manually configure port forwarding to direct incoming traffic on selected ports from the primary router to the secondary one. Again, though, you'll need to configure this twice, so that the secondary router forwards connections on to the appropriate client.

It also allows the router to provide internet services to all the other devices on your LAN; when a computer on your network wants to connect to (say) wikipedia.org, the router forwards the request over the internet. The remote server sees the connection as coming from your router's external IP address, but this isn't a problem: it sends data back, and the router in turn passes it back to the originating system. The latter process, whereby the router takes care of directing internet packets to and from the devices on your LAN, is called Network Address Translation, or NAT for short.

05 So how do I access my devices over the internet?

NAT works brilliantly when the connection is initiated by a computer inside the LAN, but it doesn't work if an external computer is trying to connect over the internet to one of your devices, because in this scenario your router has no way of knowing which internal IP address the traffic is intended for.

This makes it impossible for attackers to hack into your computers and home devices by trying IP addresses at random. However, it's a problem if you want one of your systems to be accessible over the internet – if you're running a web server on a Raspberry Pi, for example, or a media server on a NAS appliance.

You can get around this using a clever feature that's built into TCP, which is the protocol that computers use to connect to one another (as distinct from IP, which defines the structure of the data they then exchange). Whenever one system initiates a TCP connection with another, it has to specify which virtual "port" it

wants to communicate on. Conventionally, this gives a clue as to the purpose of the connection: for example, port 80 is normally used by web browser software wanting to connect to a web server, while port 401 is used for controlling and interacting with an uninterruptible power supply.

You can use this information to point connection requests in the right direction. If you're running a web server on your Raspberry Pi, it will probably be listening on the default port 80. You can therefore go into your router's port-forwarding settings and configure it to forward all incoming connections on port 80 to the internal IP address of the Pi. The next time the router receives an

incoming connection request on that port, it will direct it onwards to the Pi, and then pass the response back to the originating internet address.

You don't always have to set up port forwarding by hand. Some applications use a protocol called UPnP (Universal Plug and Play) to communicate with your router and automatically set up the required rules. Security experts have recommended disabling this feature on your router, however, because it can be used by malware to open up attacks from malicious servers. You might decide it's worth the risk: you should have good anti-malware defences in place regardless of whether you're using UPnP or not. ■

WHATEVER HAPPENED TO IPV6?

The implementation of IP in use today is actually the fourth version of the standard, commonly known as IPv4. It was introduced in 1982, and at that time the four-octet address format – representing a total of 4,228,250,625 unique addresses – doubtless seemed quite generous.

As internet usage exploded in the 1990s, however, it became clear that sooner or later IPv4 was going to reach its limit. The architects of the internet foresaw that at some point every possible IPv4 address would be allocated, and it would become impossible to connect any more devices to the internet.

Clearly a new addressing system was needed. Version 5 of IP had already been designated as a system specifically for video streaming (although it never caught on), so in 1998 a new general-purpose system was drafted under the name IPv6.

IPv6 is similar to IPv4, but instead of four octets it uses a series of eight 16-bit numbers (sometimes called hexets), conventionally written in hexadecimal form with the numbers separated by colons, so a valid address might be 0201:0db8:0000:0006:00ba:1234:5678:0090. To make things slightly more readable, leading zeros can be omitted and zero values can be skipped altogether, so that address could also be written as 201:db8::6:ba:1234:5678:90.

This arrangement might not be snappy, but it allows IPv6 to support 340,282,366,920,938,463,463,374,607,431,768,211,456 different addresses

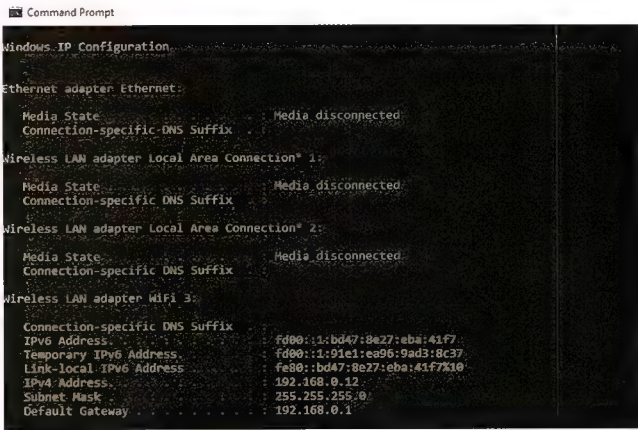
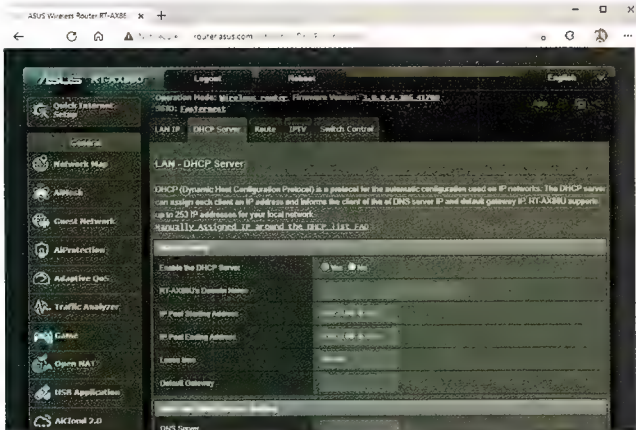
– enough to allow each person on earth to own 44 octillion connected devices. It's safe to say that everyone who wants an IPv6 internet address will be able to get one, and it even makes NAT obsolete: on an IPv6 LAN, every device in your home or office can have its own globally unique internet address, with the router simply acting as a gatekeeper.

If you're wondering why we don't already have IPv6, the answer is that we do – it's been built into Windows since Windows XP SP1. The trouble is that IPv6 isn't directly interoperable with IPv4, and the cost and upheaval of migrating online services, home appliances and so forth has so far ensured that IPv6 remains a niche technology.

Various measures have been taken to keep IPv4 up and running for as long as possible. The internet authorities have been reclaiming and reissuing IPv4 address blocks that were previously issued to organisations that are no longer in existence, while some companies have been buying up unused addresses from businesses that no longer need them.

In the long run, though, internet providers will inevitably have to start offering IPv6-only connections, and the dominoes will necessarily fall from there. And while this may mean short-term pain, it will also bring benefits. IPv6 is more efficient than IPv4, so it should mean faster and more reliable networks. And at the very least, it will mean that ISPs and IT departments worldwide will no longer

Below left: Your router provides internet services to all your devices. Below: IPv6 is built into Windows, but it's still a niche technology.





WHAT IS IT GOOD FOR?

There's more to Windows' filing system than you might realise. Darien Graham-Smith explores NTFS's hidden depths – and its limitations.



You probably don't spend a lot of time thinking about how files and data are organised on your hard disk. You don't need to: when you buy a new PC, its system drive will invariably come formatted as NTFS. This is Windows' native file system, and using it ensures that you get the full performance and storage features supported by the platform.

NTFS isn't your only option, however. For example, if you buy a second hard disk for your desktop PC, or an external SSD to connect to a laptop, you have several options for formatting it. That also applies when you divide a hard disk into separate partitions, perhaps so you can dual-boot a PC into Linux. NTFS may be the default choice, but it could be that a different file system suits your needs – or you might find that NTFS works even better than you realised.

Why do we need NTFS?

NTFS was introduced as part of Windows NT 3.1 back in 1993. This was the first edition of Windows to be designed specifically for businesses; in everyday use it looked and worked almost identically to Windows 3.1 (the version number was chosen to emphasise that), but beneath the surface NT offered powerful new security and management features.

The file system was a big part of that. Windows 3.1 had inherited the MS-DOS file system, known as "FAT" after the File Allocation Table that it used to divide up your hard disk. FAT supported basic features like nested folders and custom file attributes, but it offered zero in the way of access security: anyone who sat down at the keyboard could read and change any files they wanted. The NT File System introduced a UNIX-like system of file ownership and permissions, which helped businesses to protect and manage their data.

Another shortcoming of FAT was that it didn't support partitions larger than 2GB, and it didn't take long for the typical PC hard disk to grow beyond this size. Users were increasingly forced to split their disks into multiple volumes. The upgraded FAT32 system, released in 1996, extended the maximum disk size to 32GB, but this too soon became restrictive. NTFS, meanwhile, had supported hard disk sizes up to 256TB from day one, growing to 8PB in subsequent releases of Windows NT.

And so, when Microsoft decided to merge the consumer and NT

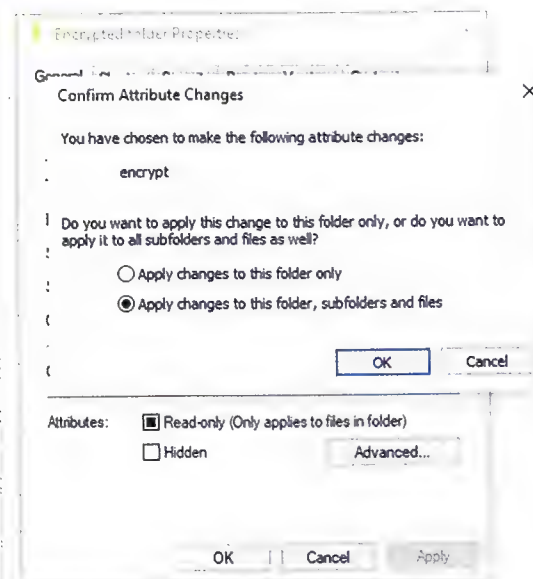
platforms into a single OS version called Windows XP, it was an easy decision to pick NTFS as the single standard file system.

NTFS can save disk space

As well as improving file security and disk capacities, NTFS includes many other features that were originally designed for businesses, but which can also be useful on a home computer. Some have been present from the very start, while others were added in Windows NT 4 and Windows 2000; all of them remain available in the latest versions of the OS.

One is native compression, which can help you squeeze more data onto a hard disk of limited size. This is disabled by default, but enabling it couldn't be easier: simply right-click on an NTFS volume in the Windows Explorer, then open the Properties window and tick "Compress this drive to save disk space". Hit the OK button and Windows will set about

Above: Native compression helps squeeze more data onto your hard disk.



Below: NTFS lets you encrypt files and folders with a couple of clicks.

compressing the entire contents of your drive, while you can carry on working as before. From now on, Windows will transparently take care of compressing and decompressing your files as you access them, with no need to change any other settings or update your applications. Indeed, the only way you'll know your files are compressed is that an image of two arrows appears overlaid on their Explorer icons.

Inevitably, NTFS compression comes with a certain impact on system performance: compressing and decompressing files takes time and CPU power. To minimise the impact, NTFS uses a lightweight compression system called LZW, which works by identifying repeated sequences of data inside a file and replacing them in the stored copy with much shorter references. This doesn't save as much space as more sophisticated compression algorithms, but its effect on performance is normally unnoticeable in typical desktop tasks, and it still produces worthwhile space savings – a typical system drive might get an effective capacity boost of around 15 percent.

If you're still wary, one great thing about NTFS compression is that it doesn't have to be an all-or-nothing setting: you can leave your Windows OS and applications untouched, for maximum performance, and apply compression only to your data files. Just open the Properties window for the folder you want to shrink, click the Advanced button and tick "Compress contents to save disk space".

NTFS can protect your data security

The access controls built into Windows make it hard for intruders to browse or manipulate your data, but if someone circumvents the OS and boots into the Recovery Console (or a third-party recovery environment), they can still browse the contents of your hard disk.

One way to prevent this is to use BitLocker, which encrypts the entire disk; that feature isn't included in Windows 10 Home, however, and may be overkill if you need to protect just a few sensitive items. A simpler solution is to use NTFS's built-in encryption feature, known as Encrypting File System, or EFS.

As with compression, you can apply encryption to a file or folder by opening its Properties window, clicking the Advanced tab and ticking the relevant box. This might not seem to have any immediate effect, but if

Encrypting File System



Back up your file encryption certificate and key

Creating this backup file helps you avoid permanently losing access to your encrypted files if the original certificate and key are lost or corrupted.

- **Back up now (recommended)**
You should back up the certificate and key to removable media.
- **Back up later**
Windows will remind you the next time you log on.
- **Never back up**
You could lose access to your encrypted files.

Cancel

Why should I back up the certificate and key?

you look closely in Explorer you'll see that the icons for encrypted files are now overlaid with padlock symbols. You can make them more conspicuous by switching to the View tab in Explorer, clicking Options to open the Folder options dialog, then switching to this window's View tab and ticking "Show encrypted or compressed NTFS files in colour". With this setting enabled, the names of encrypted files will appear in green, while compressed ones will be shown in blue.

Although your selected files are now encrypted, you'll still be able to open and save them just as before. This is because the encryption key is tied to your Windows user account;

as long as you're logged on, Windows automatically decodes and re-encrypts items as needed, using the industry-standard RSA algorithm. However, if anyone else logs on and tries to open your files they'll just see an error – and if they inspect the data from outside of Windows, all they'll find is an impenetrable block of seemingly random bytes.

While EFS is great for protecting sensitive data, it comes with a warning. When you first enable encryption, Windows will prompt you to back up your encryption key to removable media; you should definitely do this. Otherwise, if you lose access to your Windows account, you'll also lose access to

Capacity:
27.2 GB

File system
NTFS (Default)

Allocation unit size
4096 bytes

Restore device defaults

Volume label

Format options
☒ Quick Format

Start Close

Far left: Make sure you back up your encryption key to removable media. **Left:** NTFS is the default option for formatting a new hard disk.

WINFS: THE NEXT-GENERATION FILE SYSTEM THAT NEVER WAS

Although NTFS works fine for most people's needs, it hasn't been updated in more than 20 years. Surely someone's had some fresh ideas about data storage since then?

Someone has. In 2003, Microsoft unveiled the first beta of a whole new file system called WinFS. Strictly speaking, this was an extension that sat on top of NTFS, but it brought a radical new approach to storage, treating the disk not as a simple repository for binary data but as a database.

Under WinFS, applications would save information using standardised schemas for images, documents, sound files and so forth, with extensive metadata to describe and expose the contents. This provided a powerful way for users to search for and access the information within their files, and for programs to extract and use data created by other applications – a key principle of Microsoft's next-generation Longhorn project, which would eventually become Windows Vista.

However, while WinFS worked as a proof of concept, it was slow compared to "raw" NTFS, and applications required major rewrites to take full advantage of it. At the time, commentator Paul Thurrott predicted that "until third-party developers support WinFS with truly innovative applications, it's unlikely that this technology will be of much interest to anyone".

Vista, meanwhile, was falling behind schedule (the intention had been to launch it in 2003; it didn't appear until four years later). To keep things moving, Microsoft decided the new OS would launch with the tried and tested NTFS, and that WinFS would be added in at some later date. Eventually, the project was abandoned.

While WinFS is gone, it's not forgotten. In a 2013 "ask me anything" session on Reddit, Bill Gates identified WinFS as the cancelled Microsoft project that he most wished had shipped. In his view, the idea failed because it was simply "ahead of its time" – and he predicted that the concept would re-emerge in the cloud era, with the server and client parsing and understanding data much more deeply than at present. The vision of WinFS could yet have its day.

your encryption key – and hence to all your encrypted items.

NTFS can recover lost data

One of NTFS's unsung features is its ability to store multiple streams of data within a single file – which can include older versions of recently updated files. This technology underpins Windows' slightly sinister-sounding Volume Shadow Copy service, which is used by Windows' System Restore to roll back the state of your Registry and system files if your computer is misbehaving.

The Shadow Copy service can also restore personal files that have been overwritten. To browse older versions of a file, right-click on it, select Properties, then click on the Previous versions tab to browse (and optionally restore) the available snapshots.

If you don't see anything here, it's probably because Windows automatically manages the amount of space that's reserved for shadow copies, and it has a tendency to zealously purge old data. Microsoft offers some advanced administrative tools for managing shadow copies – you can download the command-line Diskshadow tool from tinyurl.com/APC506SHADOW.

For most of us, however, it's easier to use the File History feature, which you'll find in the Settings app under Backup. This works on disks of all types, and won't automatically delete old copies of files. Backups made with File History appear in the Previous versions tab alongside those created by the Shadow Copy service, or they can be viewed by selecting a file in Explorer and clicking the History button on the Home tab.

NTFS can help organise your files

One final feature of NTFS worth mentioning is links – a simple idea that can be enormously useful for

organising your files and folders. At their simplest, links work just like shortcuts in Windows: if a particular file or folder is buried in an inconvenient location on your disk, you can create a handy direct link to it from anywhere you like.

The difference is that Windows shortcuts only work in contexts where you can double-click on them. NTFS links operate at the file system level, so they're transparent to applications. For example, if you have a program that insists on looking in a particular folder for a large data file, you can move that file to a different location – perhaps an external drive – and replace the original with a link.

You can create NTFS links from the Command Prompt using the `mklink` command, or from PowerShell by entering `New-Item-Type` followed by `SymbolicLink`, `Junction` or `HardLink`. These three types of link have subtle but significant differences. A symbolic link redirects all access to the target file or folder, which can be located on any disk or network share; a junction does a very similar job, but only works for directories located on the same computer. Technically speaking, a symbolic link is handled by the client, while a junction is processed by the server – but on a home network the distinction is normally academic.

A hard link is a slightly trickier idea. When you make a hard link, NTFS effectively creates a new file on your hard disk, with its own attributes and permissions, but pointing to the same on-disk data as the original file. This means if you delete either file, you'll still be able to access the data from the other, whereas deleting the target of a symbolic link will just leave you with a broken link. Hard linking provides an easy way to have the same file in two locations at once without wasting space or worrying about divergent changes, though for obvious reasons it only works for files on the same disk.

Why not use NTFS for everything?

NTFS has clear advantages over the file system that preceded it, but not every application needs them. For example, a microSD card that's used to store images from a digital camera, or to transfer songs onto a smartphone, doesn't require advanced access security. Building NTFS support into consumer gadgets like this would add unnecessary complexity – and it

would also push up the cost, as NTFS is a proprietary technology that needs to be licensed from Microsoft.

For these roles, FAT remains an attractive choice. It's simple, mature and free to implement. The 32GB limit is no longer a deal-breaker either, as modern implementations can work with partitions of up to 2TB in size. And because FAT32 has been the de facto standard for data exchange since the early days of digital cameras and MP3 players, it's fully supported by almost every type of device, from security cameras and dictaphones to MacBooks and Linux servers.

By contrast, the encumbrances of NTFS mean that, nearly 30 years after it was introduced, cross-platform support is very limited. You can plug an NTFS volume into a Mac and it will be recognised, but in read-only mode: write access is deemed "experimental" and is enabled at your own risk. If you need a production-quality read/write solution for NTFS, you'll need to pay \$30.35 for Paragon's third-party driver (see tinyurl.com/

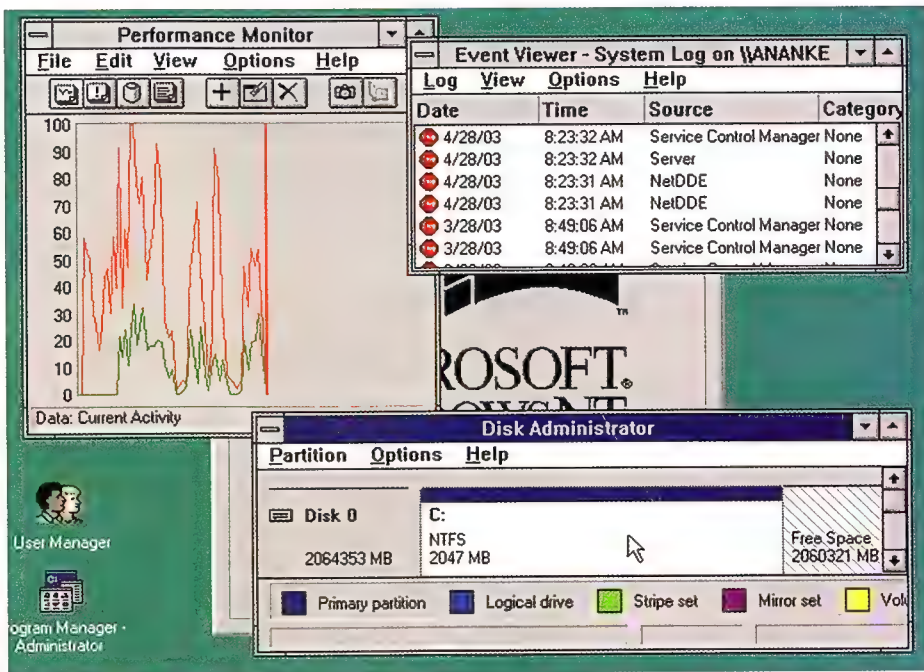
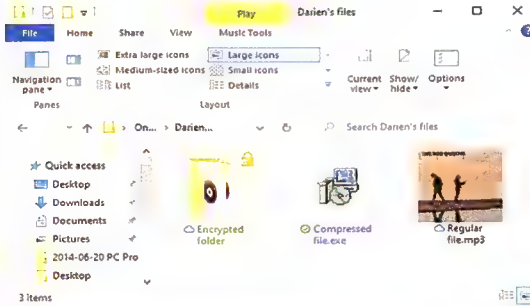
APC506PARA). Linux, meanwhile, allows read and write access to NTFS volumes through the free NTFS-3G driver, but it's much slower than FAT or Linux's native ext4 file system.

This is the best reason to avoid NTFS. If there's any chance you'll want to share files across platforms, FAT is a more portable format. If you need to turn an NTFS volume into FAT (or vice versa), then by far the easiest way is to reformat it, but there are plenty of free tools out there that can perform an in-place conversion.

There is one remaining limitation of FAT32 to bear in mind: while the file system now supports large disks, individual files still can't be any bigger than 4GB. This is why, when you're shooting video, your files sometimes get inconveniently split into multiple parts. Thankfully, there's a solution – if your devices are smart enough. The latest version of FAT, known as exFAT, ups the maximum drive size to 128PB, with no limit on the size of individual files (strictly speaking, there is a limit, but at 16 exabytes it's much larger than the maximum disk size, rendering the matter moot).

All Windows and Mac systems can read and write exFAT volumes – and thanks to Microsoft opening up the standard in 2019, it works on a growing number of third-party devices, too. If you need access controls or other advanced features on Windows then NTFS remains your best bet, but for external storage exFAT has a lot going for it. ■

Below: Encrypted files can be shown in green, compressed files in blue.
Bottom: NTFS was introduced in Windows NT 3.1 back in 1993.



System news

A resurgence in CPU overclocking has Mark Williams drooling over the possibilities.

The joy of unlocking hidden performance in a CPU via overclocking has been around for decades. In the last few generations of CPUs AMD and Intel have wised-up to how GPUs have been self-boosting based on thermals and available power overheads available at any moment, meaning that while high-end CPUs can still be overclocked manually, how hot a CPU gets is typically the main factor in unlocking extra performance. That for the most part means that under-volting of all things, is now the primary way to gain more performance in these hot top-end CPUs. If your chip can use a little less voltage and not crash, less power is used, which in turn means less heat, which in turn means the CPUs can boost to higher clock speeds for longer periods.

It's really impressive and clever what AMD and Intel are achieving now in terms of giving customers products that are capable of self-extracting as much performance as possible without human intervention. It does of course mean overclocking lately has been kind of dull as a result, as overriding single core-boost algorithms means you usually suffer lower single-thread performance for marginal multithreaded gains, which typically for gamers isn't the desired use case and has left many resorting to the mantra of just whack a big cooler on it, under-volt it a tad, and let the CPU manage itself for the best gains.

Recently, though, YouTube'r der8auer posted his discovery that 12th Gen non-K Intel CPUs – which have locked multipliers and aren't meant for overclocking – could in fact be overclocked on particular motherboards.

These special motherboards were mostly Asus-branded (Strix B660-G, Strix B660-F, Maximus Z690 Apex etc), though now Asrock's B660 Steel Legend has also shown itself to be capable.

The trick? These motherboards all have an external clock generator and an 'unlock BCLK' BIOS option.

BCLK is typically linked with PCIe timings, RAM, USB, SATA,



AMD's 5300G, a quad-core y-cruncher (a CPU benchmarking app) record holder, has been smashed by the i3-12300 with a time almost 40 percent faster with an overclock of 5.44GHz.

and more that run off its clock timings. With 12th Gen, Intel allowed for an external clock gen that sits on the motherboard, allowing the motherboard to tune the BCLK of just the CPU and RAM, and not affect the rest of the system that before could only manage three percent overclocks at best, before system-wide instabilities kicked in.

The result? With upwards of 30 percent higher BCLKs, world records are toppling. The Celeron G6900 – a two-core 3.4GHz part – was able to achieve 5.34GHz, a 57 percent increase! AMD's 5300G, a quad-core y-cruncher record holder, has been smashed by the i3-12300, with a time almost 40 percent faster with an overclock of 5.44GHz.

This feature has set alight the



MARK WILLIAMS
Mark is an IT professional with a strong interest in voiding warranties.

overclocking community again, and all of a sudden makes the i5-12400F – with its six performance cores – even more tantalising if you're willing to tinker.

Intel has said all the usual things, like this voids your warranty and they aren't designed for it, but the funny thing is Intel also says that about the high-end K-SKUs as well, it's just hidden it away in the fine print.

With word that motherboard makers are investigating bringing this functionality to cheaper motherboards that also support cheaper DDR4, we could see a minor overclocking renaissance once again where it all began in lower end parts, making them equal or better than their more expensive brethren for less money.

SHOP TALK

What is the most popular non-K Intel 12th Gen CPU you're selling at the moment?

Richard, AftershockPC:

"For our systems we are just using the 'K' and 'KF' models; not currently doing the non-K models. We find our customers much prefer the K/KF models (even if they don't necessarily take advantage of the unlocked processor) so have reduced our SKU lineup by just offering those. For our gaming range, we use KF across the board since every one of our builds comes with a dedicated GPU and hence the integrated GPU is really not necessary. For some of the workstations we just use the K (without KF offering) as specific software can really take great advantage of the integrated graphics.

We would potentially consider [using non-K SKUs], however the difference in price seems to only be around the \$10-\$20 mark (at the same SKU level) so possibly doesn't warrant the additional offering (and confusion to those that don't know the differences)."

Market snapshot

A sampling of PC systems available this month.



\$1,619 – tinyurl.com/APC506NZX

NZXT STARTER PC

Coming in as the second most expensive in this month's round-up of systems, having just gone on sale down from \$1,799, this system unfortunately still isn't good value.

The case and power supply are particular highlights of this build, both worthy of keeping through upgrades. The CPU, while two generations old, is still common in this price class. Oddly Nzxt is slapping a big Deepcool heatsink on it. Great for temperatures, but rather unnecessary and pretty much a waste of money versus the free stock Intel cooler. The slow by modern standards 2666MHz RAM is also disheartening, as is the complete lack of secondary mass storage, a common pairing with sub 1TB SSDs.

The main pain point though is the graphics card; a GTX 1650 non-Super card is quite woeful and inexcusable in this system's price range. Best avoid this one.

CPU: Intel Core i5-10400F **Cooler:** Deepcool Gammax GTE V2 **Motherboard:** Gigabyte B560 HD3 **Graphics:** Gigabyte GeForce GTX 1650 **Memory:** Gigabyte Gaming 16GB DDR4 2666MHz **Storage:** Gigabyte Aorus 500GB NVMe M.2 SSD **Power Supply:** Gigabyte GP-P650B 650W **Case:** Nzxt H510.



\$1,399 – tinyurl.com/APC506COM

CENTRE COM NIGHTHAWK GEN11 i5 1650

Centre Com is showing Nzxt how it's done from a value perspective. Offering a very similar yet still superior system, while coming in over \$200 cheaper. The 11th Gen CPU is a generation ahead, giving 100MHz higher boost clocks and supporting faster 3,200MHz memory, which this system comes equipped with. This also has an iGPU, so using QuickSync is possible with this system and can also come in handy should you need to troubleshoot the main graphics card. Speaking of which, we still have a GTX 1650 graphics included, so gaming performance will be largely similar.

The primary SSD is 500GB with a secondary 2TB hard drive for mass storage. Compared to the Nzxt also on this page it's a better and more well-rounded product that is much more in line with what it should cost.

CPU: Intel Core i5-11400 **Cooler:** Antec A40 PRO 92mm; **Motherboard:** Intel B560 Chipset; **Graphics:** Gigabyte GeForce GTX1650 OC 4GB R2.0; **Memory:** Kingston 16GB DDR4 Fury Beast C16 3200MHz; **Storage:** 500GB NVMe M.2 PCIe SSD, 2TB HDD; **Power Supply:** 550W; **Case:** Gigabyte C200 RGB.



\$1,799 – tinyurl.com/APC506PCC

PC CASE GEAR REAPER 6600 XT

This system costs as much as the Nzxt system does (when not on sale) and shows just how bad that system is for gamers. This system hits many of the same highlights with the 10400F CPU, a B560 motherboard, and a 500GB SSD. However, things begin to improve with the inclusion of a 2TB hard drive for some much-needed mass storage space, almost 1000MHz faster 3,600MHz memory, and – most importantly – a much more performant RX 6600 XT graphics card.

That graphics card is the main reason this system is the most expensive this round-up, and rightfully so, as for that extra \$180 over the discounted Nzxt system or \$400 over the Centre Com one, you can expect double the gaming performance! A good option for those a little more serious about getting their game on.

CPU: Intel Core i5 10400F; **Cooler:** OEM; **Motherboard:** Asus Prime B560M-A/CSM; **Graphics:** PowerColor Radeon RX 6600 XT; **Memory:** Team T-Force Delta RGB 16GB 3600MHz; **Storage:** Team MP34 M.2 NVMe SSD 512GB, Seagate Barracuda 2TB HDD; **Power Supply:** Phanteks PH-P550GF 550W; **Case:** Phanteks Eclipse P300A RGB Mesh Edition.

\$1,299 – tinyurl.com/APC506MWV

MWAVE MSI TRIDENT 3

Currently on sale, down from the original \$1,499, it is our cheapest system this month, yet offers 70 percent more gaming performance than the pricier Nzxt and Centre Com systems thanks to the inclusion of the GTX 1660 Super. Great, right? Well, there are some compromises to be aware of. Housed in a snazzy and thin console-like chassis, this has meant MSI had to use SODIMM memory – and only giving you 8GB of it at that, which is restrictive. Also, the power supply is an external power brick and the GPU is the short ITX variety, limiting upgrade options. There's also only a single 500GB SSD, although there is a spare 2.5-inch bay to slot in an extra drive.

Basically, this system looks good and is great value (it even comes with a free keyboard and mouse), however, upgradability and repairability are factors to consider longer-term.

CPU: Intel Core i5 10400F; **Cooler:** OEM; **Motherboard:** Intel H41; **Graphics:** MSI GeForce GTX 1660 Super; **Memory:** 8GB 2666MHz DDR4 SODIMM; **Storage:** 512GB M.2 PCIe SSD; **Power Supply:** 330W power brick; **Case:** MSI Trident.



PC BUILDER

Budget

A perfect balance between price and performance.

This month's budget improvements are focused on the Intel build, as we rebuilt the AMD one last month and were unable to find any reasonable upgrades or cost savings. There's a lot happening with Intel at the moment, including an extraordinarily priced CPU that means we can upgrade a few of the other components, as well as a new high-value GPU entry in the market. The first tweak is the Intel Core i5-12400F, minus the onboard graphics processor. You will need a discrete graphics card for this build, so if you're unable to get one, or you're holding out for whatever reason, be sure to look at the standard i5-12400 at \$319. The i5-12400F, though, is only \$40 more than the Intel Core i3-10400 we used to feature in this build but offers double-digit performance gains in both single and multi-core operations. It offers incredible bang for your buck, which is why we wanted to feature a build around it this issue.

Another component of the cover feature has made it into our budget build, the newly-released Nvidia 3050. We won't pretend these are going to be

easy to get hold of, but they are selling for a lot less online than the 3060 card we featured last month. We still wouldn't spend any more than \$600 on these cards, but it's your decision. As we found in our review this month, the 3050 is a capable little 1080p card with plenty of memory and all the usual Nvidia features we love, such as ray tracing and H265 encoding.

We also upgraded the motherboard to an LGA1700 model and chose the

cheapest ATX model we could find with the \$220 Asrock B660 Pro RS. You could get that down to \$170 with the Asus Prime H610M-E D4, but it's a Micro ATX so has fewer PCI and RAM slots. Finally, taking advantage of the Asrock motherboard's PCIe Gen4 port, we pinched the XPG Gammix S50 Lite SSD from the AMD build and put it into the Intel one. This will offer speed benefits over the previous 500GB Samsung 980 NVME but costs only \$15 more.



AMD INGREDIENTS

PART		PRICE
CASE	Corsair 4000D Airflow	\$130
PSU	550W Corsair CV550 80+ Bronze NEW	\$75
M/BOARD	MSI MPG B550 Gaming Plus AM4	\$190
CPU	AMD Ryzen 5 3600	\$309
GPU	MSI Radeon RX 6700 XT 12 GB MECH 2X	\$1,100
RAM	16GB (2x 8GB) Crucial Ballistix CL16 @ 3600MHz	\$118
SSD	512GB XPG Gammix S50 Lite PCIe 4.0 M.2 SSD	\$115
HDD	4TB WD Blue 5400 HDD	\$120
OS	Windows 10 Home 64-bit OEM (Win 11 Compatible)	\$60
PRICE		\$2,217

INTEL INGREDIENTS

PART		PRICE
CASE	Corsair 4000D Airflow	\$130
PSU	550W Corsair CV550 80+ Bronze	\$75
M/BOARD	Asrock B660 Pro RS NEW	\$220
CPU	Intel Core i5-12400F NEW	\$289
GPU	Gigabyte RTX 3050 Gaming OC NEW	\$599
RAM	16GB (2x 8GB) Crucial Ballistix CL16 @ 3600MHz	\$118
SSD	512GB XPG Gammix S50 Lite PCIe 4.0 M.2 SSD NEW	\$115
HDD	4TB WD Blue 5400 HDD	\$120
OS	Windows 10 Home 64-bit OEM (Win 11 Compatible)	\$60
PRICE		\$1,726

PC BUILDER

Mid-range

A game-ready machine that can also handle demanding work.

Not too much change on the mid-range front this issue, but on the plus side, there were some cost savings to be made. The dependable, but 18-month-old, AMD Ryzen 5 5600X dropped in price this month, perhaps reflecting Intel's competition in this price bracket. That's not to knock this six-core, 12-thread processor, though, which is still more than capable of complementing the Radeon RX 6800 XT, a new entry last month. Speaking of graphics cards, both the Nvidia RTX 3070 GPU we picked last month and the RX 6800 XT in the AMD build are still holding steady despite slight falls in general across the graphics card market.

Last month's power supply option, the Corsair RM750x, hasn't seen a price drop and even though we like this fully modular power supply the 750W EVGA SuperNova GA is slightly cheaper and just as capable, thanks to its 80+ Gold rating and fully modular design.



The other tweak we made this month was to the AMD's motherboard. The Asus AM4 TUF Gaming X570 Plus WiFi went up about \$20 this month – still good value for all that it offers, but more expensive than Asrock's gaming focused-board. The Asrock includes Wi-Fi, and it offers all the important features you'd want from a mid-range board, including a PCI Express 4.0 M.2 slot for the super-fast Samsung 980 Pro drive.

We've had the 280mm Cooler Master

Masterliquid ML280 Mirror ARGB in both Intel and AMD builds for a little while now, and while the price hasn't fallen – it has remained extremely competitively priced for a few months. But in the spirit of offering an alternative that still has the chops to keep either CPU cool we've elected to go with a Cooler Master Masterliquid ML240L RGB V2 for the Intel build. It's 240mm compared to the larger 280mm Masterliquid ML280 Mirror ARGB, but the \$54 saving is too hard to resist.

AMD INGREDIENTS

PART		PRICE
CASE	Lian Li PC-O11-Dynamic	\$209
PSU	750W EVGA SuperNOVA GA 750 W NEW	\$139
M/BOARD	Asrock X570 Phantom Gaming 4 NEW	\$199
CPU	AMD Ryzen 5 5600X	\$339
COOLER	280mm Cooler Master Masterliquid ML280 Mirror ARGB	\$149
GPU	MSI Gaming Radeon RX 6800 XT 16 GB	\$1,599
RAM	16GB (2x 8GB) Corsair Vengeance RGB Pro SL RGB CL16 @ 3600MHz	\$135
SSD	500GB Samsung 980 Pro NVME M.2 PCIe 4.0 SSD	\$149
HDD	4TB WD Blue 5400 HDD	\$120
OS	Windows 10 Home 64-bit OEM (Win 11 Compatible)	\$60
PRICE		\$3,098

INTEL INGREDIENTS

PART		PRICE
CASE	Lian Li PC-O11-Dynamic	\$209
PSU	750W EVGA SuperNOVA GA 750 W NEW	\$139
M/BOARD	Asus Prime Z690-P LGA 1700	\$249
CPU	Intel Core i5-12600K	\$449
COOLER	Cooler Master Masterliquid ML240L RGB V2 NEW	\$95
GPU	MSI Ventus GeForce RTX 3070 8 GB	\$1,340
RAM	16GB (2x 8GB) Corsair Vengeance RGB Pro SL RGB CL16 @ 3600MHz	\$135
SSD	500GB Corsair Force MP600 M.2 PCIe 4.0	\$149
HDD	4TB WD Blue 5400 HDD	\$120
OS	Windows 10 Home 64-bit OEM (Win 11 Compatible)	\$60
PRICE		\$2,999



PC BUILDER

Turbo

The maximum PC.

It's good news this time around for our AMD build, a \$100 sale on the powerful AMD Ryzen 9 5900X brings our CPU down to \$699. Unfortunately, the Ryzen 5950X hasn't been struck with the same luck, otherwise, we'd swap chips here. This processor is, of course, no slouch and is still one of the best offerings from AMD right now.

To help costs and get some extra speed improvements, we opted for the Sabrent Rocket 4 Plus 1TB SSD over the previous Samsung 980 Pro of the same capacity. The price is essentially the same, but it's a win-win scenario here, with increased read/write speeds. The rest of the build doesn't change, prices remain roughly the

same with a few fluctuations on the cooler and motherboard. The Asrock Radeon RX 6900 XT is still available and prices haven't altered, so that is one step in the right direction. We are also keeping the MSI MAG CoreLiquid 360R ARGB in both builds (at least, that was the plan...). This is a neat-looking cooler that will do the trick in both high-end rigs.

On the Intel side, we see a sale on our i9-12900K CPU, not quite as good on this side of the fence but any decrease in price is welcome. We have a few more changes on this build though, kicking things off with a price drop that has made us extremely happy. For a small increase of \$50, we swap out our

Gigabyte RTX 3080 for the Ti variant. This model brings us 12GB of GDDR6X, 2GB more than the standard 3080 offering from Gigabyte, and was a no-brainer.

A compatibility issue meant that we had to swap out the newly added MSI MAG CoreLiquid 360R ARGB cooler for the Corsair iCue H150i RGB Pro XT. With the same 360mm radiator size, it should perform similarly, although it's not as quiet or cheap as the MSI offering. And that was it for the changes on the Intel Turbo build, albeit they were some pretty exciting ones. The only other differences were similar to those on the AMD machine, with a few price alterations but nothing to worry about. ■

AMD INGREDIENTS

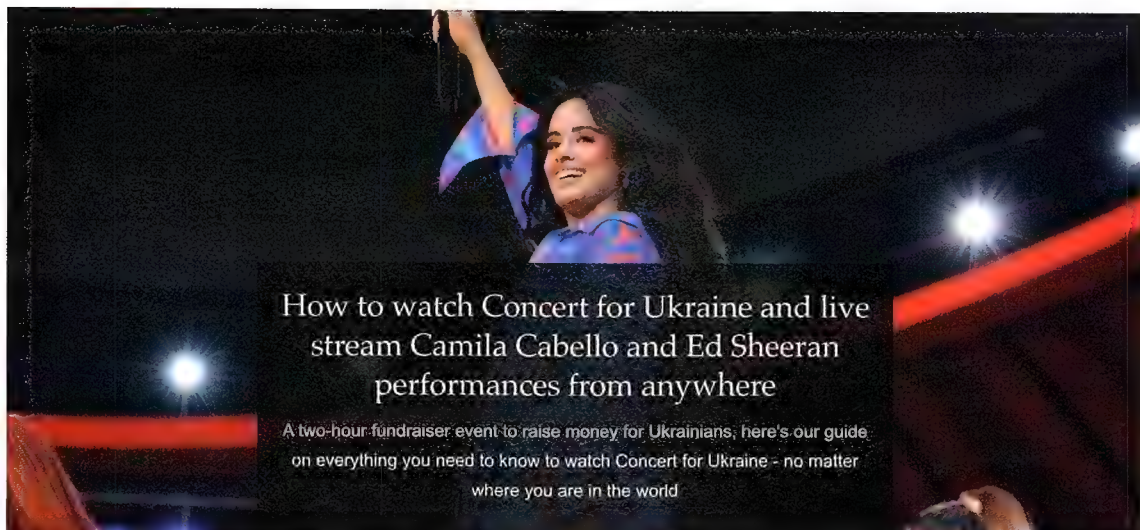
PART		PRICE
CASE	Phanteks Enthoo Pro 2 Tempered Glass	\$210
PSU	750W Be Quiet! Pure Power 11 FM 80+ Gold	\$148
M/BOARD	Gigabyte X570 Aorus Elite	\$195
CPU	AMD Ryzen 9 5900X	\$699
COOLER	MSI MAG CoreLiquid 360R ARGB	\$169
GPU	Asrock Radeon RX 6900 XT Phantom Gaming D 16GB	\$2,200
RAM	32GB (2x 16GB) G.Skill Ripjaws V 32GB @ 4000MHz	\$309
SSD	Sabrent Rocket 4 Plus M.2 PCIe 4.0 NEW	\$269
HDD	6TB WD Blue 5400 HDD	\$240
OS	Windows 10 Home 64-bit OEM (Win 11 Compatible)	\$60
PRICE		\$4,499

INTEL INGREDIENTS

PART		PRICE
CASE	Phanteks Enthoo Pro 2 Tempered Glass	\$210
PSU	750W Be Quiet! Pure Power 11 FM 80+ Gold	\$148
M/BOARD	MSI PRO Z690-A WIFI LGA1700	\$329
CPU	Intel Core i9-12900K	\$899
COOLER	Corsair iCUE H150i RGB PRO XT NEW	\$219
GPU	Gigabyte Gaming OC GeForce RTX 3080 Ti 12GB Gaming OC NEW	\$2,299
RAM	32GB (2x 16GB) Kingston FURY Beast DDR5 @ 5200MHz	\$409
SSD	1TB Gigabyte Aorus Gen4 M.2 PCIe 4.0 SSD	\$249
HDD	6TB WD Blue 5400 HDD	\$240
OS	Windows 10 Home 64-bit OEM (Win 11 Compatible)	\$60
PRICE		\$5,062

TRENDING

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I tried the Sony A95K QD-OLED TV, and it wasn't what I expected

Sony's next-gen QLED showed me quiet realism more than abundant colours and brightness

BY MATTHEW BOLTON • PUBLISHED 21 HOURS AGO



I tried a new Dolby Atmos soundbar that puts my Sonos Arc to shame

The Devialet Dione delivers the the best bass I've ever heard from a one-box soundbar

BY MATTHEW BOLTON • LAST UPDATED 1 DAY AGO



Why Nothing Phone excites me more than iPhone 14 or Samsung Galaxy S23

Nothing just announced Phone (1) and it's got me very excited

BY MAX SLATER-ROBINS • LAST UPDATED 1 DAY AGO



Nintendo delays Breath of the Wild 2 but promises "something special"



Dynamic DNA test review



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Quick Tips

The problem solvers

The APC team field problems across the spectrum of devices and software. Learn a new trick or fix you can use.

PC won't post to BIOS

I've had my computer since 2013: Intel i5-4670K, Gigabyte GA-Z87X-UDH3, 16GB Corsair Vengeance DDR3 1600MHz RAM (two 8GB sticks), housed in a Thermaltake case and powered by a CX Series 80 Plus Bronze CPU. When I try to boot, the PC turns on for about two seconds, then turns off and tries to reboot without success. I can't even get into the BIOS.

I've switched out the power supply, tried only one stick of memory, and switched out the CPU cooler to no avail. I suspect the motherboard is at fault, but nothing obvious shows on the board. Your advice would be appreciated.

Paul LoGrasso

APC Responds: Assuming you've already stripped the machine back to its core – booting with all non-essential external peripherals and internal components (including drives and expansion cards) disconnected, the lack of any LED debug codes to offer even a hint of what might be going wrong does suggest the motherboard has reached the end of its life.

You could try dismantling and rebuilding from scratch. This would enable you to inspect each component and put them back in place. Make sure the case is clean and, after rebuilding the minimum required to boot, try again. It's a long shot, but it may fix problems caused by chip creep, loose screws (like short circuits), and other mechanical faults.

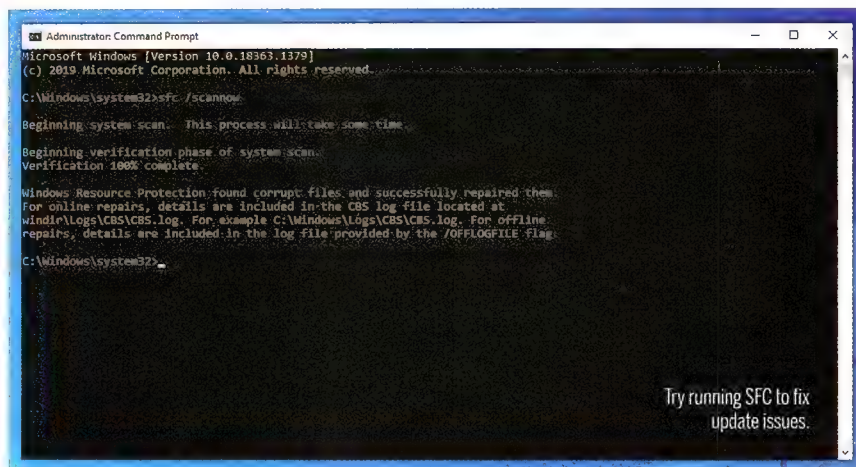
Windows Update error

I'm trying to prep an old laptop for a Windows 11 upgrade. It's compatible, but I've not used it in so long that when I go to Windows Update it tells me the current version has reached end of service. I try to update to the latest one offered (20H2), but it fails with error code 0xc190012e.

John Gannon

APC Responds: There are many causes of this problem, but one clear path to follow in trying to resolve it.

I'm trying to prep an old laptop for a Windows 11 upgrade. It's compatible, but I've not used it in so long that when I go to Windows Update it tells me the current version has reached end of service.



First, we asked John to remove his third-party security software (McAfee), switch to 'Settings > Update & Security > Troubleshoot', and click 'Run the troubleshooter' under Windows Update. It detected problems and invited John to retry the update, but it failed again. He ran `sfc /scannow`, which found errors and was able to fix them, but still the update refused to budge.

We switched our attention to the Windows Update Assistant. As Windows 11 requires version 2004 or later, John first had to go to www.microsoft.com/software-download/windows10 and click 'Update now' to download and run the Windows 10 Update Assistant. However, this got a different error: "There was a problem running preinstall.cmd scripts".

At this point, we consulted with John who confirmed there was nothing on the laptop worth keeping, so rather than wrestling with this failing Windows 10 installation, we went straight to Windows 11. John had already confirmed his laptop was compatible using the Windows 11 PC Health Check App (aka.ms/GetPCHHealthCheckApp) – third-party alternatives, such as WhyNotWin11 (github.com/rcmaehl/WhyNotWin11), will give a more detailed explanation. Subsequently, it was a case of directing him to download the Create Windows 11 Installation

Media Tool (www.microsoft.com/software-download/windows11) to create a bootable USB flash drive, then install Windows 11 fresh from that. Skip the request for a product key during installation – Windows will upgrade the laptop's Windows 10 digital license during activation.

Saving old PCs

I had a Ryzen 5 2400G running on a Gigabyte Aorus B450 Pro Wi-Fi, with 32GB RAM and 500GB Samsung EVO M.2 NVMe boot drive plus 2TB hard drive that I built two years ago. I was running the Windows 11 Pro Insider Preview (Dev channel) when I discovered the Ryzen wasn't compatible with Windows 11 due to the well-known TPM issue, so I purchased a Ryzen 7 5700G. I had to update the BIOS and do a clean reinstall but am now running a great system with no problems. I will have to build a new system for my wife because her system isn't compatible, despite running Windows 10.

I have been repairing older computers to be donated to senior groups in need and it's too bad that these computers will soon be bricks because of TPM. It's simply hard luck on those who can't afford a new box.

Rick G

APC Responds: Did you know that TPM 2.0 can be added to many systems even when the CPU itself doesn't support it? That's because TPM can be rendered one of two ways: through the CPU's own firmware, or through a discrete module on the motherboard

itself. Even if your CPU fails the TPM check, all may not be lost.

Many motherboards come with a header for connecting plug-in TPM modules (check your motherboard manual), enabling you to render TPM support directly from the motherboard. There's no standard header, so you'll probably need to source the TPM module from your motherboard manufacturer.

Originally available for \$30, the value of these chips soared on the back of the original announcement that Windows 11 would require TPM 2.0 support. Taking Rick's PC as an example, his Gigabyte Aorus B450 Pro board supports the Gigabyte GC-TPM2.0 module. At the time of writing this is widely available from most Australian resellers for around \$25. Take care when buying these – some offer chips for multiple manufacturers within a single listing, so select the correct one. Look for listings that provide detailed descriptions and pin diagrams to help you pick the correct module.

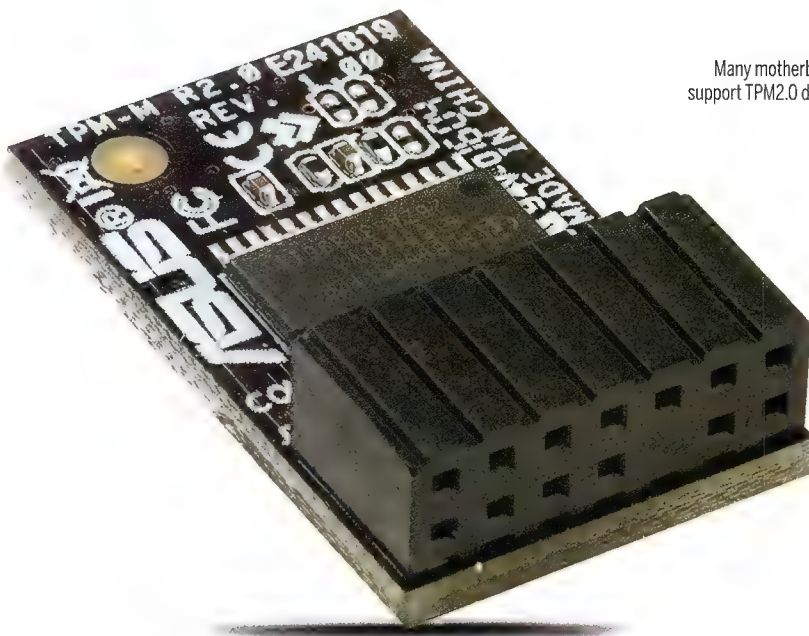
For those PCs locked out of Windows 11, Windows 10 will continue to be supported until 2025, which buys a little time for those without the funds to buy a new box. Should you be desperate to move to the newer version, you can bypass this check for now (see the following question) but APC also wonders if now isn't the right time to take another look at Linux. There are some great user-friendly distros out there to tempt you away – Ubuntu, Mint, Elementary, and Deepin Linux to name but four.

Virtualising TPM 2.0

In your response to Morris Pomey's question ('Boot Camp Updates', you indicate that Parallels "creates a 'virtual' TPM chip to meet the Windows 11 TPM 2.0 requirement". This confirms my theory that Microsoft could create virtual TPM 2.0 functionality to allow Windows 11 to run on older hardware. Performance might be slower, but I doubt that chip is being pounded every microsecond. Or am I inferring too much from the statement?

Gary Lavery

APC Responds: APC's cynical side says if this were possible, it would have already happened. The TPM 2.0 requirement was a deliberate choice by Microsoft to lock out older hardware. This is shown by the fact Windows 11 can run on machines without the TPM 2.0 chip by instructing Windows to skip the TPM check through a Registry tweak. This can be applied whether you're planning to upgrade an existing Windows 10 installation or do a clean install.



Many motherboard's support TPM2.0 directly.

Originally available for \$30, the value of these chips soared on the back of the original announcement that Windows 11 would require TPM 2.0 support.

In both cases, it's carried out through an administrative command prompt – if you're upgrading Windows, type 'cmd' into the Search tool and click the option to 'Run as Administrator'. If you're using installation media to perform a clean install, follow the setup wizard to the point where you're told your PC has failed the upgrade check, then press Ctrl-F10 to open a command prompt window, then type the following command and press Enter:

```
REG ADD HKLM\SYSTEM\Setup\LabConfig /v BypassTPMCheck /t REG_DWORD /d 1
```

Upgraders can now launch the update through Windows, while those opting for a clean install should close the command prompt, then click Back in the install wizard before proceeding as normal. The issue with this workaround is that there's no guarantee it'll work forever. What's to stop Microsoft from closing the loophole or blocking updates to systems where no TPM 2.0 chip has been detected?

The irony is that you can run Windows 11 in a virtual environment on systems that fail the TPM 2.0 check – that's true for Microsoft's own Hyper-V virtualisation solution that ships with Windows 10 Pro.

If this approach appeals, then when creating your virtual machine with Hyper-V, select 'Generation 2' at the 'Specify Generation' screen. After the VM has been set up, open its settings to the Security section, where you should enable Secure Boot, select Microsoft Windows from the Template dropdown, and tick 'Enable Trusted Platform Module' before clicking OK.

Insider prisoner

Little did I know when I signed up for Windows Insider Preview that along would come Windows 11. I'm running Windows 10 Pro on an HP Z800 that can't run Windows 11 but, as Windows Preview tries to install Win11, I keep getting, "This build of Windows will expire soon".

Is there any way I can get back on track without having to jump through the backup and reinstall Windows 10 Pro circus?

Frank D Gunseor

APC Responds: It appears you're running on the Dev channel of Windows Insider – confirm this by going to Settings > Update & Security > Windows Insider Program. If you're on Release Preview or Beta channel, you could switch this off and revert to regular Windows 10 updates from the next major release (22H2, due later this year).

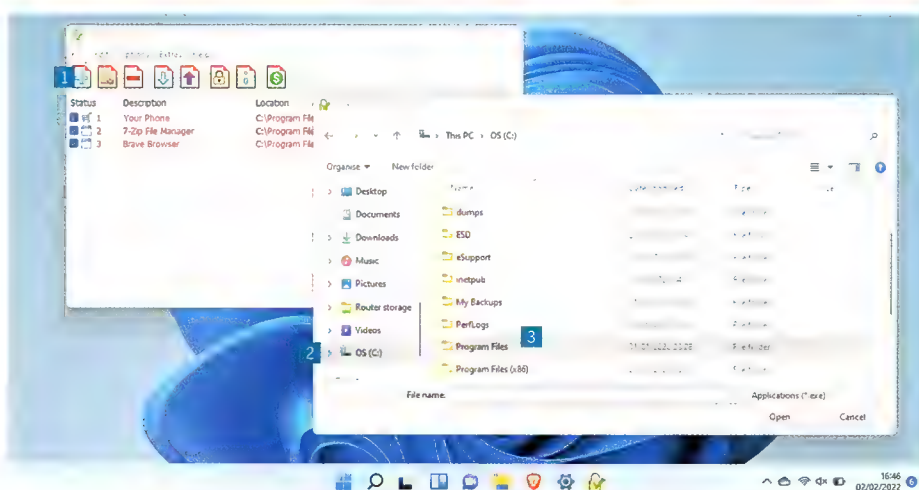
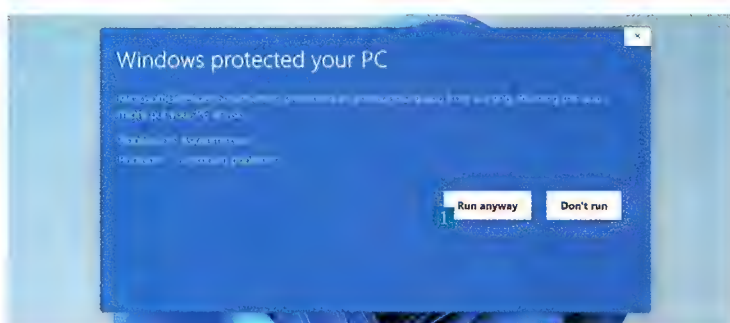
The fact you're receiving this message suggests otherwise – had you been in the Beta channel, Microsoft would have moved you to the Release Preview channel when your laptop failed to meet the requirements. So, you'll need to make a backup and then download the latest Windows Media Creation tool (www.microsoft.com/software-download/windows10) to create the Windows 10 installation media you'll need to wipe your system drive clean and install a fresh copy of Windows from scratch. ■

Stop people using selected software on your PC

What you need: AskAdmin **Time required:** 30 minutes

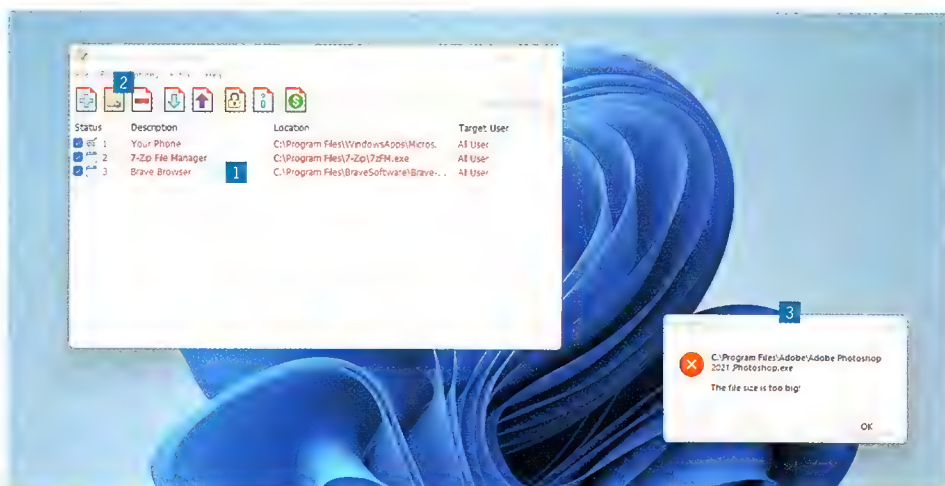
If you share your PC with other family members – especially younger ones or those new to computing – you may want to restrict what they can access. There are various tools you can use to do this, but one of the most effective is AskAdmin. Tell it what software you want to restrict, and it will prevent it from launching, without you having performed any complex configuration behind the scenes. And, should you later want to authorise a program you need to use, rolling back your changes is very straightforward.

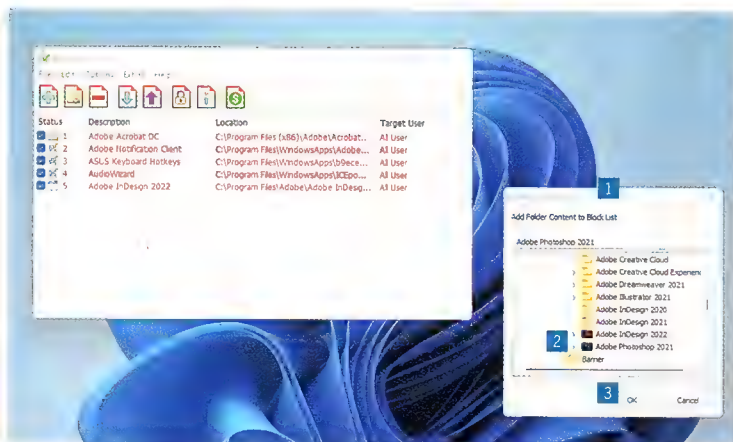
01 Visit www.sordum.org/downloads/?askadmin and, if AskAdmin doesn't start downloading automatically, click Direct Download. When the download is completed, switch to File Explorer and click Downloads in the sidebar. Double-click 'AskAdmin.zip' to expand it, then open the AskAdmin folder and click the 'AskAdmin_x64.exe' file. Windows SmartScreen may warn you that AskAdmin comes from an unrecognised developer, but it's perfectly safe so click 'More info', then click 'Run anyway' **1**. User Account Control will now ask if you want AskAdmin to make changes to your device. Click Yes. Once AskAdmin is up and running, you can start building your list of protected programs.



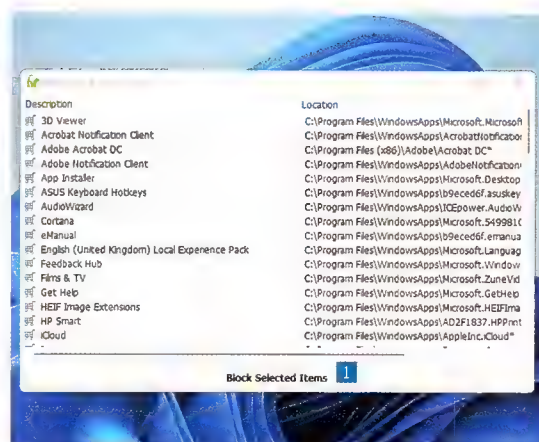
02 To add your first program, click the '+' button ('Add File to the Block List') **1** on the left of the toolbar. This opens a File Explorer window. Click the C: drive in the sidebar **2**, then Program Files or Program Files (x86) in the main part of the window **3**. The former is where Windows stores programs on a 64bit system, the latter is for 32bit programs. There's no hard and fast rule as to where you'll find the program you want to block, so, if you don't choose the right folder first time, try the other one. Bear in mind that most programs will be stored in their own sub-folder inside one of these parent folders.

03 When you've found a program you want to block, select it and click Open. It will be added to the block list **1**. However, we found that AskAdmin won't add extremely large programs **2**. For example, Adobe InDesign (7MB) was added to our list without problems, but Adobe Photoshop (139MB) couldn't be added. A workaround is to click the 'Add Folder Content to Block List' button **3** instead.

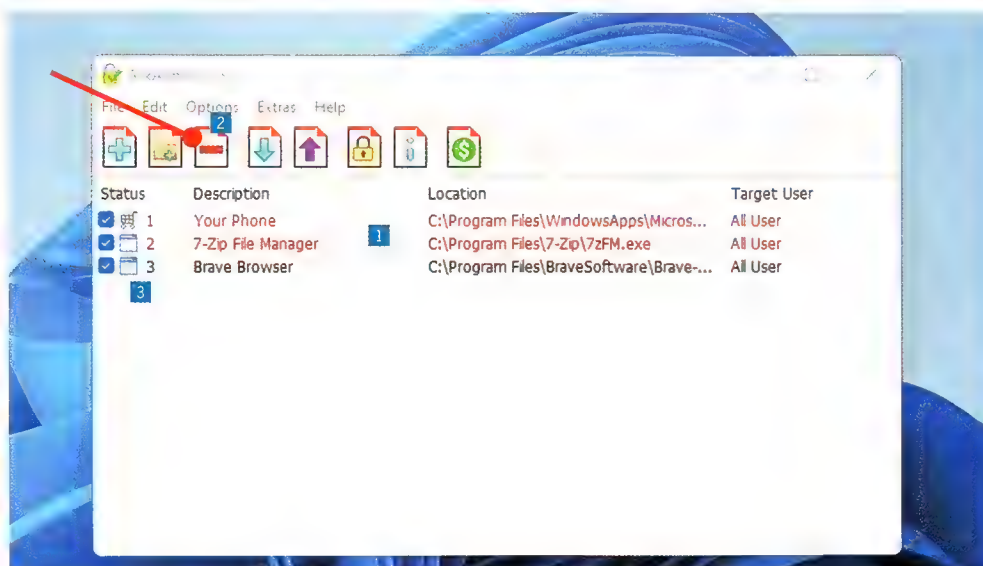




04 When adding a folder, keep digging down in the 'Browse for Folder' window **1** until you reach the lowest possible sub-folder containing the program you want to block. So, using Photoshop as our example, this is found in a folder called 'Adobe Photoshop 2021' which sits in an Adobe folder inside Program Files. If we simply add 'Program Files', we'd block all our 64bit programs and, if we added Adobe, we'd block every program in the Creative Cloud suite. So, we'll select Adobe Photoshop 2021 **2**, then click OK **3**.

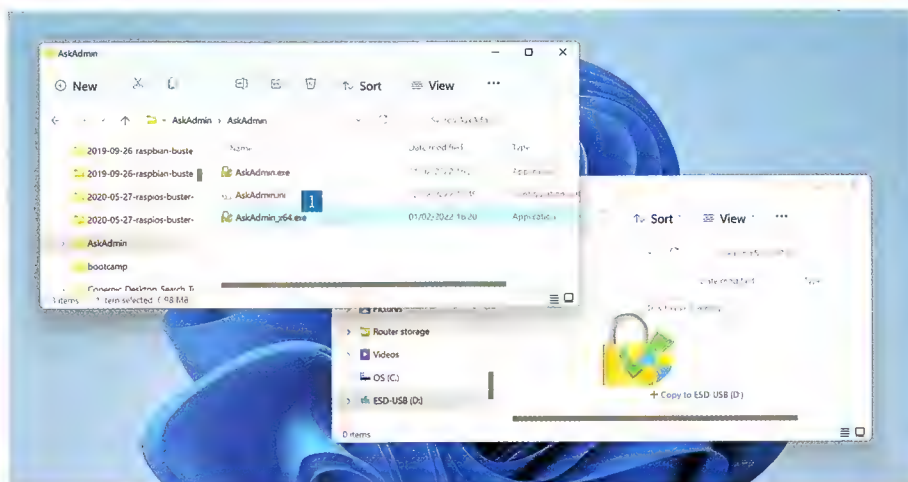


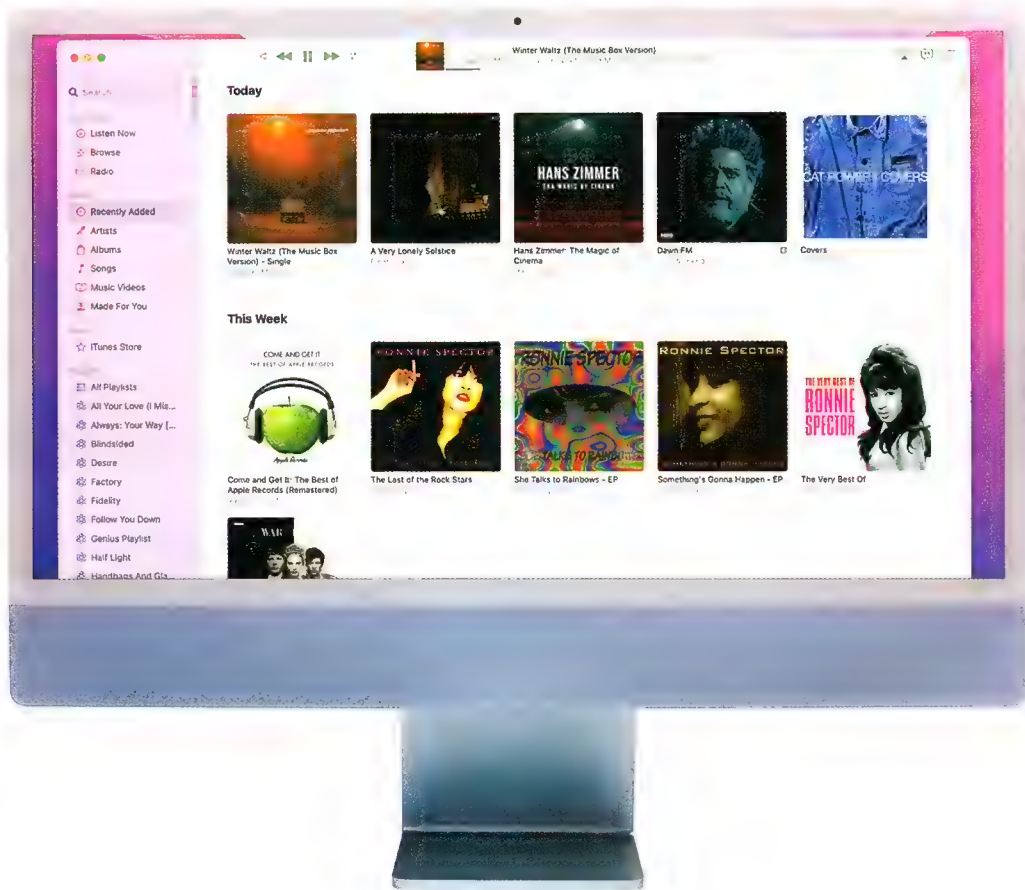
05 You don't need to add all your programs at once: you can keep coming back to AskAdmin to refine the list over time. If you want to add apps from the Microsoft Store, click Extras, followed by 'Block Built-in (UWP) Apps'. Rather than opening a File Explorer window, this pulls up a list of installed programs. Click the first one you want to add to the list and, if you want to add any others, hold down the Ctrl key while clicking each in turn. Finally, click Block Selected Items **1**.



06 When you've added all the programs you want to block, you can quit AskAdmin and, should anyone try to launch one of the programs you've added to the list, they will be warned that it's been blocked by the system administrator. If you want to unblock a program in future, launch AskAdmin again, and simply delete it from your list by clicking it in the programs window **1**, then clicking the Remove Selected button **2**. To temporarily unblock a program, don't remove it from the list: just untick the box beside its name instead **3**.

07 You'll notice that, although you downloaded AskAdmin to your computer, you didn't install it, as you would via a browser. That's because AskAdmin is a portable program that can be run from anywhere, including a USB stick. To copy it to a USB stick, plug it in, then drag the 'AskAdmin_x64.exe' file **1** from the AskAdmin folder inside Downloads to the stick. You can then delete the AskAdmin folder from your computer, and run the program from the stick instead. That way, nobody who has access to your computer will also have easy access to the program that unlocks the software they're forbidden from using. ■





APPLE MAC

Tidy your music library

Move your music library to an external drive or use multiple libraries.

IT WILL TAKE
30 minutes

YOU WILL LEARN
How to backup and move your music library, and run two libraries

YOU'LL NEED
Apple Music

In this Apple Music tutorial, we're going to deal with libraries. In Apple-speak, your music library is where Music stores details of all the files you have imported, downloaded or added from Apple Music's streaming service, as well as information about playlists.

The library is not, as we'll see, necessarily where the music itself is stored. That could be on Apple's servers, in a different folder on your Mac, or on an external drive.

Whatever you like

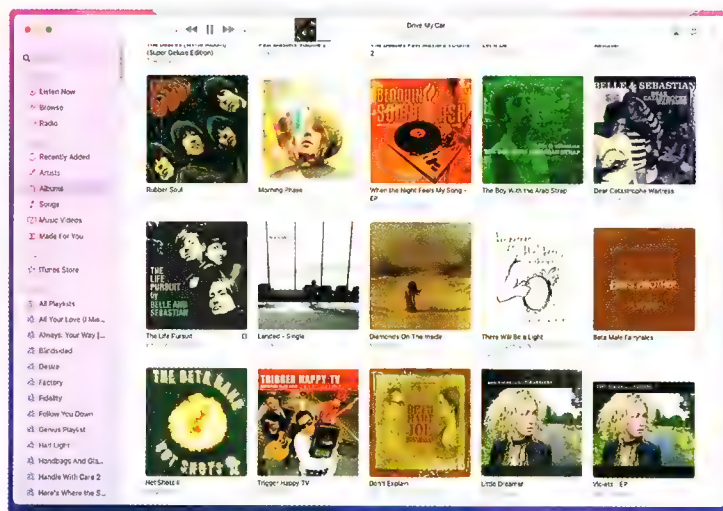
It's likely that the music you

play in Apple Music is stored in multiple places. And if you use iTunes Match, everything will also be stored on Apple's servers, whether it's downloaded, streamed, or ripped, or even your own songs made in Logic or GarageBand. In the latter case, iTunes Match uploads your file to its servers. For CDs you've ripped or songs downloaded from a non-Apple service, it 'matches' tracks against its database and allows you to stream those versions.

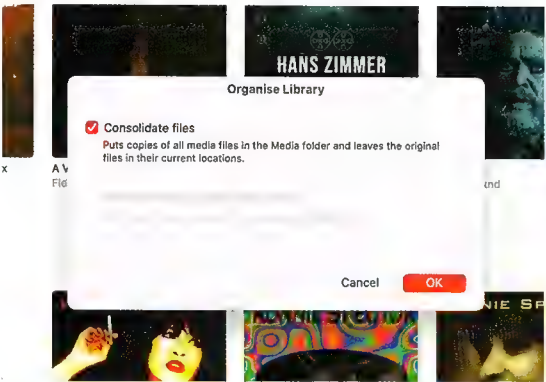
We'll show you how to consolidate your library, move it to a different location, and run multiple libraries. It's important to note that wherever you store music, tracks that you've bought on the iTunes Store or downloaded from Apple Music's streaming service are protected and can only be played when signed into an Apple ID that has permission to play them.

Kenny Hemphill

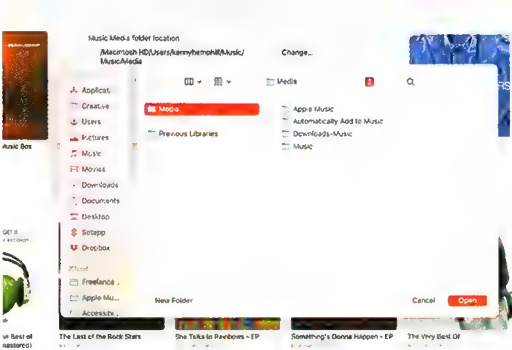
Your library houses tracks you've imported, songs you've downloaded, and those you've added from Apple Music's streaming service.



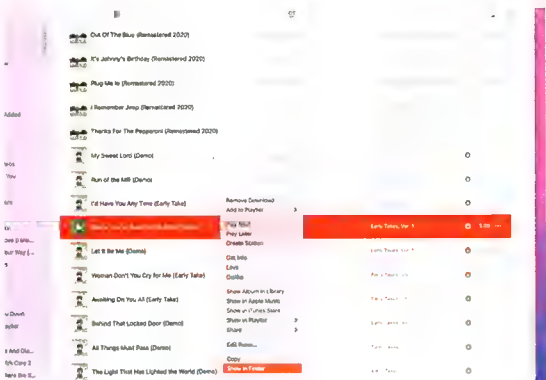
HOW TO Sort your music libraries



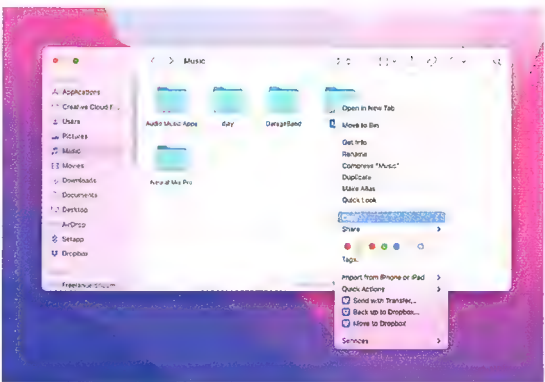
01 Consolidate your library
Consolidating your music library places copies of all your music to one folder and leaves originals in place. In Music, choose File, then Library and Organise Library. Check the box next to 'Consolidate files' and click OK.



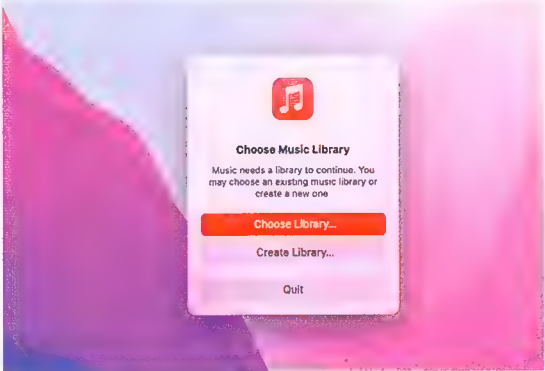
03 Tell Music about the folder
Once you've copied the folder, you need to tell Music where it is. Go to Music > Preferences and choose Files. Click Change and navigate to the new library folder. Click Open to select it as your default Music library.



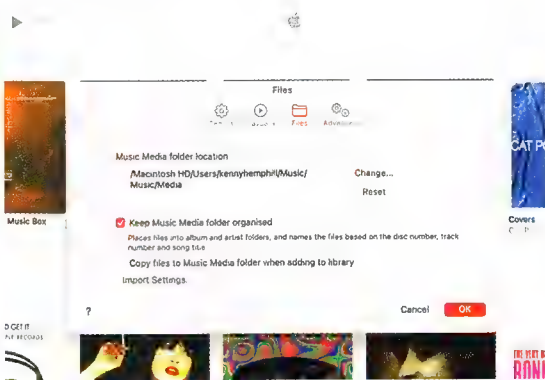
05 Find a music file on Mac
If you're not sure where a song is stored on your Mac, click Songs in the Music sidebar, locate the song, select it and click the File menu then choose 'Show in Finder'. If 'Show in Finder' is greyed out, the file isn't on your Mac.



02 Move your Music folder
Once you've consolidated, moving your music just a matter of copying the ~/Music/Music folder in the Finder to a new location. You can also delete the original versions of the songs you consolidated in step 1 to save space.



04 Use a different library
If you have multiple libraries, you can choose which one to use when you launch the Music app. Hold option when you double-click the Music icon, click Choose Library, navigate to the Music Library file and click Choose Library.

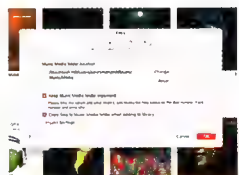


06 Change import location
By default, imported files are moved to the folder that houses the rest of your music, usually ~/Music/Music. To change that, go to Music > Preferences > Files and uncheck 'Copy Files to Music Media Folder when adding...'



JARGON BUSTER
The **Library** is the file that holds data about your music, whereas the **Media** folder is where the actual audio files are stored.

GENIUS TIP!
Go to Music > Preferences > Files, and check the box next to 'Keep Music Media folder organised' to put songs you import into folders labelled by artist and album.



Rapid fuzzy finder

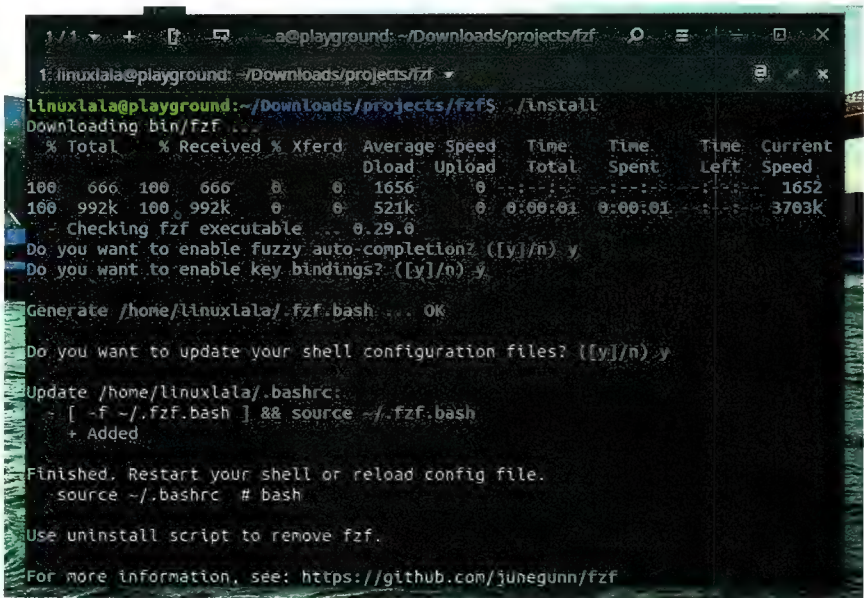
Shashank Sharma isn't one for magic, but he's not averse to using the Accio spell or its computing incarnation, fuzzy finder, to find things quickly.

When looking for files on the desktop, you may often rely on the search feature of your favourite file manager. The conventional searching approach is to apply an exact search, so that only files or directory that are a perfect match to the search string are displayed. A fuzzy search, on the other hand, performs an approximate search, and instead of identifying exact matches, displays matching results with each keystroke.

The `fzf` utility identifies itself as a general-purpose fuzzy finder. Released under the MIT License, the cross-platform tools can be used across all flavours of Linux.

Installing fzf

Despite the usefulness of the tool, the project isn't offered as part of the default installation of desktop Linux distributions. However, it's available in the software repositories of quite a few. The project's GitHub page provides a list of all the distributions that carry `fzf` in their software repositories, along with the supported version. Unfortunately, the latest release, version 0.29.0, is offered only in the latest releases of distributions such as Fedora. Manjaro, openSUSE



Fzf has no dependencies at all, so installing using the install script is the easiest way to ensure you end up with the latest version.

Tumbleweed, Ubuntu, Debian and Arch, while most others carry older versions. If you're running one of these distributions that offers the latest version, you can use the distro's software management utility to install `fzf`. The command `sudo apt install fzf` can

be used to install it on Debian and Ubuntu or derivatives, while `sudo dnf install fzf` can similarly be used to install it on Fedora. Apart from using the software repositories, there are several other ways to install `fzf`, including using the package manager `homebrew`. Of course, you can also use Git to clone the project's directory to your hard disk and then install `fzf` using the install script:

```
$ git clone --depth 1 https://github.com/junegunn/fzf.git
$ cd fzf
```

```
$ ./install
```

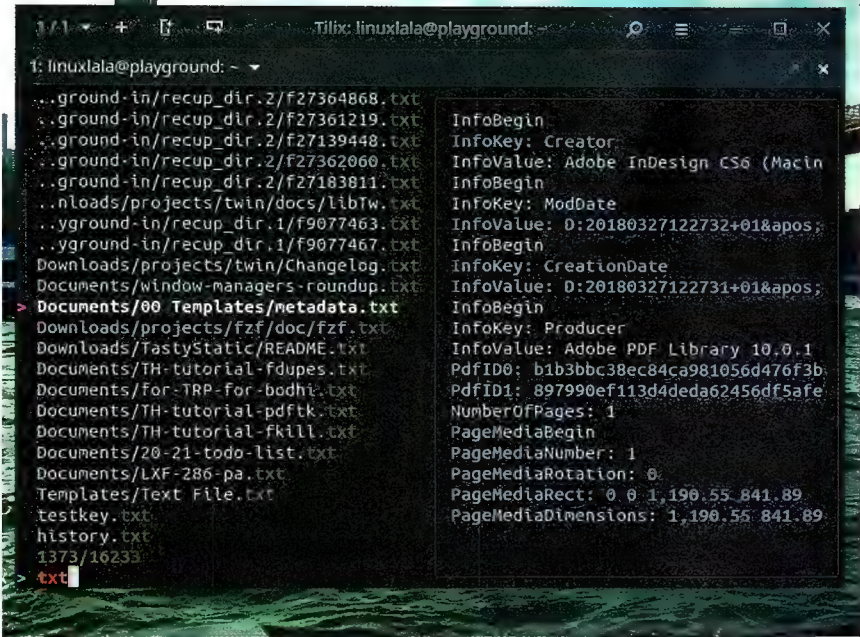
The `fzf` tool supports auto-completion and various key bindings. The install scripts asks if you wish to enable these and also offers to edit your `~/.bashrc` file. Once enabled, you'll be able to deploy the following key-bindings to invoke `fzf`:

Keybinding	Function
Ctrl-r	Search the recent command history based on \$HISTFILE
Ctrl-t	Recursively search for the filename in the \$PWD
Alt-c	Recursively search for a directory name under the \$PWD, and cd into the selected directory.

Despite the usefulness of the tool, the project isn't offered as part of the default installation of desktop Linux distributions. However, it's available in the software repositories of quite a few.

RELATED PROJECTS

You can assess the popularity and usefulness of `fzf` by the fact that the project maintains a list of related projects on its Github hosted wiki (<https://github.com/junegunn/fzf/wiki/related-projects>). This is a collection of other tools and utilities that build on the functionality of `fzf` to offer an improved CLI experience. Consider the `fzf-extras` utility (<https://github.com/atweiden/fzf-extras>), for instance, which adds additional key bindings or the `fzf-marks` (<https://github.com/urbainvaes/fzf-marks>) utility, which enables you to quickly create bookmarks to various directories. The page lists projects across many different categories such as Tmux, Vim, Bookmarks and Shell. Many of the listed projects haven't seen a new release in quite some time, but these are simple tools offering very limited functionality, so don't let that deter you from trying them out. You'll also find several projects under the 'Similar implementations' heading. These are projects that provide functionality similar to `fzf`. Pick (<https://github.com/mpetre/pick>) is one such project, although it doesn't have the same degree of documentation as `fzf`. While `fzf` is written in Go, you can also try your hand at Skim (<https://github.com/lotabout/skim>), which is a fuzzy finder with identical feature set, but written in Rust.



This is how you can preview a file with fzf without opening it. The 800 line-plus man page discusses this and other features in detail.

While fzf may seem like a straightforward tool to use – and it is – don't let its simplicity fool you. The project is incredibly versatile in its use and offers myriad capabilities to improve your CLI experience.

Working with fzf

The *fzf* tool is only a finder so it makes little sense to invoke it by itself. Instead, you can use it in conjunction with other commands such as *cd*, or to open files in a text editor such as *vim* or *nano*.

Before we try that, let's start with something simple. Press *Alt+c* and see the directory lookup in action. This feature only works with the *\$PWD*. So, if you're in your *~/* directory, you'll be able to narrow down directories on your *~/Desktop*, *~/Documents* and so on, but not in the */media/* directory, for instance.

This opens an interactive prompt and starts recursively indexing all the directories in the *\$PWD*. Start typing some words and the results will change with each keystroke. When you see one that you want, select it and press *Enter* to change into the directory.

Although you can use up and down arrow keys to navigate the search results produced by *fzf*, the tool also supports *Ctrl-j* or *Ctrl-n* to move down and *Ctrl-k* or *Ctrl-p* to move up through the results.

You can exit the fuzzy search by pressing *Ctrl-c* or hitting the *Esc* key. In a departure from behaviour for most command-line utilities, *fzf* also boasts of mouse support, so if you're

more clicking than keystrokes, you can use the left-click to select and the scroll wheel to navigate the *fzf* generated results. You can also double-click an entry to change into the directory.

You can even use *fzf* as a replacement for tab-completion. To invoke *fzf* tab-completion, you must use the **** identifier with a command:

```
cd **<tab>
>
18/18
>Books
temp
temp/repo
temp/repo/data
temp/new
DHC
DHC/circulars
```

As you can see, here we used the *fzf*-tab-completion with the *cd* command, which opens the interactive search prompt and provides a list of matching directories. As you type in keywords, *fzf* will narrow down matching results. This makes changing directories easy because you don't have to write long path names, or repeatedly use the *Tab* key to perform completion. You can easily select a directory, even 10 levels deep, with a handful of keystrokes at the most.

You can also use the **** tab-

completion with the *kill-9* command to identify the process you wish to kill, or if you frequently use *ssh* to connect to remote devices even use the *ssh **<tab>* command to select the remote host.

The **** tab-completion works with a large number of commands. Run the complete *| grep _fzf* command for a complete list of all supported commands.

By default, *fzf* starts in extended-search mode, which means that you can type space-separated keywords to narrow down the file or directory you're looking for. However, you can also utilise different techniques to improve the search results.

Token	Regex	Explanation
string	string	Searches for string
	'string'	Performs an exact match for items that include the quoted string
^string	^APC	Lists items that start with APC by performing a prefix-exact-match
.format\$	.odt\$	Lists files that end in .odt format by performing a suffix-exact-match
!string	!dhc	Lists items that don't include dhc by performing inverse-exact-match
!^string	~^APC	List items that don't start with APC by performing inverse-prefix-exact-match
!.format\$	!.odt\$	Lists files that don't end with .odt format by performing inverse-suffix-exact-match

While *fzf* may seem like a straightforward tool to use – and it is – don't let its simplicity fool you. The project is incredibly versatile in its use and offers myriad capabilities to improve your CLI experience.

One such useful feature is the preview, which enables you to preview a file as soon as you select it, without opening it first. This works by opening a preview in an additional pane on your terminal window using an external tool such as *cat* or *less* to preview the contents of a file. To begin, make sure to read the man page to get a better sense of the tool's capabilities. You must also check out the wiki on the project's GitHub page (<https://github.com/junegunn/fzf>) which is home to various examples. ■

DIY

DIY Bluetooth audio for less than \$3

You don't need to spend hundreds to get wireless audio speakers. Use your existing audio system and build your own Bluetooth setup for less than the price of a coffee. Darren Yates explains.

Wireless audio has transformed the way many of us listen to music, but I find portable Bluetooth speakers often leave me a bit flat. Sure, they're convenient and everything, but in some cases, I think I'd almost rather listen to a cat stuck up a drainpipe. Ever since British engineer Alan Blumlein invented stereo in 1931, scientists and engineers have pushed the boundaries to improve audio quality and, as usual, Australia has punched well above its weight in this pursuit. Neville Thiele is remembered as an Australian engineer, who, along with Dr. Richard Small from the University of Sydney, developed scientific methods for measuring speaker parameters and speaker enclosures in the 1960s. They're collectively known as 'Thiele/Small' or 'TS' parameters and are still used in high-performance speaker systems all around the world today. Sure, the golden age of Hi-Fi has long gone, but if you already have a decent speaker setup (gaming speakers or home theatre for example), you can turn it into a Bluetooth system for less than the cost of a coffee. Here's how.

Golden ears

Now, just before we get going, no doubt most audio purists will scoff at the idea of adding Bluetooth to anything and expecting better quality audio – and to some extent, I agree with them. Bluetooth's Advanced Audio Distribution Profile (A2DP) has the potential to support lossless audio codecs, like the new aptX Lossless from Qualcomm (who make phone chips, among other things). However, in practice, many cheaper Bluetooth audio devices will be lucky to support anything beyond the basic SBC

(sub-band coding) codec because it's free for manufacturers to implement.

I take a pragmatic approach – I'll use Bluetooth for convenience, but when I really want to actively listen to music, I'll play my CDs through my Hi-Fi system with floor-standing speakers. However, the one problem I often find with Bluetooth speakers is they lack

The BT audio receiver takes power from USB and outputs audio via a 3.5mm socket.

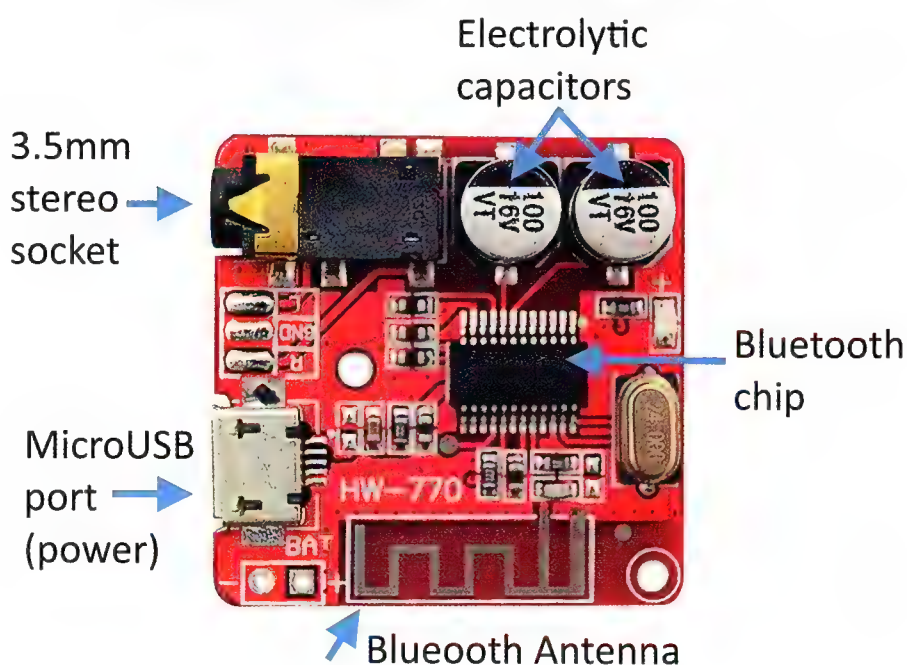
This \$3 board is not much larger than a postage stamp.

decent low-or 'bass' frequency response and sound 'boomy'. Put simply, sound waves are just changes in air pressure and to get good bass frequency response, you need speakers that can move a decent volume of air at that low frequency. But to get that, you need speakers either big enough or powerful enough to do the job.

What you'll need

The key component of this project is a small circuit board a bit larger than a postage stamp called a 'bluetooth audio receiver module'. You'll also need an old good-quality phone charger, a microUSB phone cable and an audio cable to suit your speakers. It'll need a 3.5mm stereo plug on one end and whatever your audio/speaker system needs on the other. If you've plugged your phone into your speaker setup previously, use that cable. The microUSB phone cable just carries power to the board.

Bluetooth Audio Receiver Module



DIY Bluetooth Wireless Audio

Bluetooth audio technology is ridiculously cheap these days – at time of writing (early-March 2022), you could pick up a BT5.0 audio receiver board from Ebay for as little as \$2.73 (and that's including shipping). All you do is plug in the phone-end of a USB cable into the board's microUSB socket, the other end into your phone charger. Next, plug in the 3.5mm stereo plug into the BT board's headphone-style socket and the other end of the cable into your speaker system.

Pairing your phone

Hooking the system into your phone is easy too. These boards have a blue LED that flashes when waiting to pair to another Bluetooth device and typically have a password that's '0000' or '1234' (check with the seller before you buy for the password). Once the board fires up, you'll usually hear a female voice saying 'the bluetooth device is ready to pair' or something similar. Now fire up your phone, head to the Bluetooth option in Settings, turn on the Bluetooth adapter if you haven't yet done so and search for new devices. The board may appear as 'JH_BT' or 'SBS' or something else non-descript. Select it (do not check the 'allow access to your call history' checkbox) and you should soon hear the voice again saying 'the Bluetooth device is connected successfully'. Now you just use it as you would any Bluetooth speaker. You can remotely adjust the volume via your phone – just set the volume control at the speaker system to a suitable level to begin with.

Usage tips

The sockets on these Bluetooth audio receiver boards are only

Connect your phone via Bluetooth and connect the audio to your speaker system.

Leave the 'Allow access to your contacts and call history' checkbox unchecked.

Essentially, this Bluetooth board lets you add wireless audio to any amplified speaker system, whether its Hi-Fi or even your old TV – as long as it has an analog audio input, you're in business.

surface-mounted – that means it won't take much rough treatment to rip the sockets off the board. I'd get some double-sided padded tape and stick the board to the side of the desk or speaker and just leave it there. The board itself consumes no more than 50mA of current, so any good-quality phone charger will do just fine.

Can you plug your headphones into the socket instead? Yes, but for safety, I'd only do so if the board is powered by battery or an earthed power source – you can't be too careful with phone chargers.

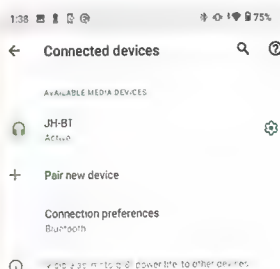
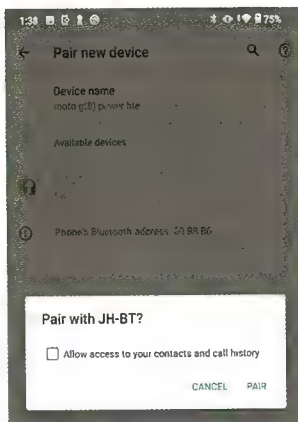
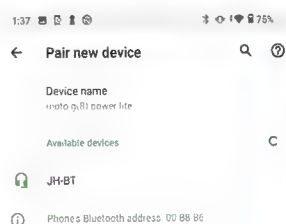
Also, don't put the board in a metal container – the squiggly trace on the board is a receiving antenna to pick up the 2.4GHz Bluetooth signals. A metal container will block the signals reaching the antenna and you won't hear anything.

Any decent electrical store will have audio cables if you're caught short, but don't spend more than \$20 at the absolute most – oxygen-free copper cables won't likely sound any better than a decent budget option.

Essentially, this Bluetooth board lets you add wireless audio to any amplified speaker system, whether its Hi-Fi or even your old TV – as long as it has an analog audio input, you're in business. Just make sure the Bluetooth board has a 3.5mm stereo socket and you'll be fine. Sure, most new powered speaker systems now incorporate Bluetooth audio, but if you already have a good speaker setup, you don't need to get rid of it just to get wireless connectivity. For \$3, you can add it yourself.

Doing it yourself

The sheer number of modules, boards and plug-in devices now available is just staggering – and the only thing more staggering is how cheap this stuff is, even with GST, and particularly when you're not paying retail prices in Australia. If you're prepared to roll up your sleeves and have a go, building your own tech projects can teach you new skills and, in many cases I've found, save yourself some serious cash into the bargain. ■



MACHINE OF THE MONTH

SAM Coupé (1989)

John Knight examines a machine a bit too ambitious for its time.

You'll need this
A copy of **SimCoupe**
Windows and Linux are both
supported. Extra BIOS
files aren't needed.
www.simcoupe.org

If you're a fan of obscure computing gems, you're in for a treat this month. With sales figures only numbering in the thousands, the SAM Coupé is a true rarity and any working collection will cost a king's ransom.

However, this hasn't stopped it from becoming a darling of the cult computing scene. The SAM Coupé sits in a strange gap between the 8-bit and 16-bit worlds, and uses some unusual hardware. The odd experience it provides has earned it many modern fans, and enthusiastic hobbyists are still developing new software and expansions for the machine.

Development and Launch

The Coupé was developed by Miles Gordon Technology (MGT), a Welsh manufacturer that had already made a name for itself developing quality storage drives for the Sinclair ZX Spectrum. The Spectrum was growing old and its adoptive owners, Amstrad, had no intention of developing the system.

But MGT had a proposition: by using the newer (but rare) Zilog Z80B processor, their machine could theoretically deliver around twice the performance, bringing Spectrum owners into the next decade, while still being able to run the existing library.

The SAM Coupé launched in December 1989. The Z80B processor



Spectrum owners would have been deeply envious of the quality full-travel keyboard, chic styling, and removable disk drives.

Specifications

CPU: Zilog Z80B @ 6MHz **RAM:** 256KB/512KB (4.5MB maximum) **Graphics:** V512 x 192 maximum resolution, 128 maximum colours **Sound:** Philips SAA1099 **Storage:** 3.5-inch 780KB floppy, cassette **OS:** SAM BASIC, CP/M via software **Released:** December 1989 **Production:** 1989-1992, 1999 **Worldwide sales:** 12,000.

was clocked at 6MHz with 256KB of RAM, and up to two removable 780KB 3.5-inch floppy drives.

Graphically, the Coupé could display old Spectrum video modes, but otherwise had a maximum resolution of 512 x 192, with 128 colours available in lower resolutions.

Sound-wise, the Coupé really shines, with MIDI ports as standard and the same Philips SAA1099 sound chip used by Creative Labs' original Sound Blaster providing six stereo voices across eight octaves.

Software

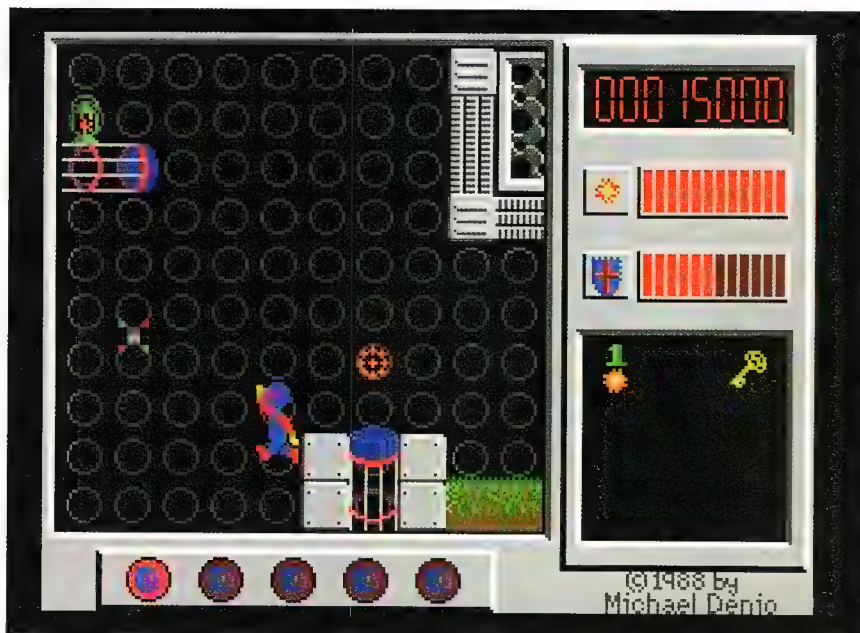
In short, Coupé software feels almost 16-bit. Although the Coupé uses an 8-bit processor, its performance is closer to early 16-bit computers. However, the Coupé lacked hardware-assisted scrolling or sprites, and having the CPU and display share RAM resulted in a speed penalty.

Nevertheless, many titles were able to work around these limitations. *Defender* (1998) faithfully recreates the original arcade experience, running at a smooth 50fps, and *The Adventures of Captain Comic* (1990) knocks the socks off the original PC release.

Arcade platformer *Defenders of the Earth* (1990) was the first major release for the system. The two biggest titles were *Lemmings* (1993) and *Prince of Persia* (1990). Other big names include an update to *Manic Miner* (1992) and *Escape From the Planet of the Robot Monsters* (1991).

The Coupé has a number of quality multimedia applications. Each Coupé shipped with *Flash!* (1989), a snazzy graphics package by ace Swedish programmer Bo Jangeborg. Musicians should check out *Sound Machine* (1991), *E-Tracker* (1992), and *SAM MOD Player* (1996), which can play Amiga sound files.

As for the modern homebrew scene, *Battle Zone* (2021) is an impressive port, *Pang* (2013) wouldn't feel out of place on a Sega Genesis, *Rick Dangerous* (2021) is another great port, and there is a sizeable collection of public domain demos.



Captain Comic (1990) is impressive and crushes the PC version thanks to a MIDI soundtrack and voice samples.

FINDING SOFTWARE

As usual, **archive.org** has a couple of good software collections, plus reading materials, and the site can worry about its own copyright problems. For something on a better legal footing, **www.worldofsam.org** has taken the time to catalog the Coupé's software archive. It only links to software that it has approval to redistribute.

So what went wrong?

Initially, enthusiasm was high. The Coupé provided a logical upgrade: it was backward-compatible with the classic 48K ZX Spectrum; tape loading was twice as fast; and the machine had near 16-bit performance levels but at a much lower price.

Software houses were expecting to be able to do quick game ports, combining Spectrum code with Atari ST graphical assets, and Sinclair magazines had dedicated SAM Coupé sections. But this dried up when a bodged launch meant it arrived late to market.

Numerous production issues meant only a small number were delivered before Christmas. Those who did get machines didn't receive floppy drives for several months. Worse still, Spectrum owners found their software was only partially compatible.

Prices for 16-bit machines were dropping steadily, which was more bad news for the Coupé. Although the base unit's launch price was attractive, if the customer added more RAM and a disk drive, this brought the machine's price nearer to that of the Atari ST.

After some warranty issues, including thousands of buggy ROM chips, MGT went bankrupt in June 1990. However, Miles and Gordon still had faith in their product, and with their own finances started a new company, SAM Computers, plus a software label, Revelation.

SAM customers finally started getting the kind of software they wanted, and Coupé prices dropped for a machine with a single disk drive.

Nevertheless, this wasn't enough to fight off established rivals, and SAM Computers was liquidated in July 1992. West Coast Computer acquired the remaining stock and began selling an updated 512KB model in 1993. These models were sold in various forms until 1999, when West Coast also shut down.

Overall, only around 12,000 units

were sold, though an active homebrew scene has continued to this day.

Emulation

The best choice of emulator is SimCoupe, by Simon Owen. It has software builds for Windows, Linux, and MacOS, plus older builds for obscure platforms.

Windows users are given a handy executable installer. Simply download and run the .exe file, and follow the prompts.

Linux users are given a 64-bit .deb file, though an older non-distro-specific binary tarball is available, plus the option to compile from source code.

If you have installed the official .deb file, you can launch SimCoupe with the command:

```
$ simcoupe
```

Usage

The Windows and Linux versions have different interfaces. The Windows version has a modern interface, whereas the Linux version is driven by the keyboard and feels almost retro in itself. Shortcut keys are the same across both versions.

As noted by the welcome screen on first boot, the most useful key bindings are:

- F1: Insert disk image
- F10: Options
- F12: Reset
- Ctrl-F12: Exit emulator
- Numpad-9: Boot drive 1

In addition to these bindings, we would also point out that F2 loads a disk image for Floppy Drive 2 and F8 toggles full-screen.

Before you get started, it's worth browsing the Options screen, under Tools > Options in Windows, or by pressing F10. The Input section has the option 'Enable SAM mouse interface', which will be essential for programs like Flash! or Lemmings.

Loading Disks

To load disk images, open the browser for Disk Drive 1 by pressing F1, or optionally for Windows users, choosing File > Open from the main menu. Open your disk file and your disk should boot automatically.

Reboot your system with F12 before loading new disks. If you're stuck on the SAM boot screen, try pressing 9 on the number pad.

While most disks should boot automatically, plenty of hobbyists' disks won't. We can't show you how to start all programs, but this is the most common scenario.

If you get an error message about 'no AUTO* file', press Enter and you will get a white cursor. Assuming you're using Floppy Drive 1, enter:

```
dir 1
```

A file list will appear with a list of file numbers on the left. Look for anything marked 'BASIC', or any other obvious loadable programs in the file list, and take note of its file number. Now enter the load command with your file number (19 in this example), like so:

```
load 19
```

If it doesn't launch after this command, enter:

```
run
```

For further troubleshooting, see the excellent manual available on the project's website. ■



The Coupé had a demo scene similar to Commodore's. Here is the Amiga Juggler demo with SAM, the robot mascot.

apc

EDITOR'S
CHOICE

\$89 | PC, PS4/5, XBL/S/X | eldenring.com

Elden Ring

A Souls-like adventure on a massive scale.

Elden Ring, FromSoftware's successor to the *Souls* series, spreads the mysteries and challenges of *Dark Souls* across an open world in a more conventional sense. There are castles to infiltrate from several angles, swamps to ride through on horseback, and gargantuan beasts to chase you down. The sheer amount of freedom is a first for the series, and it results in a game packed with what's so beloved about it: idiosyncratic characters and buckets of truly horrifying monsters.

Elden Ring features the same deliberate combat that's now iconic for these types of games, except here it's fully refined. You swing, the enemy swings, and both of you can interrupt each other's attacks with acute timing. This is upended by the new weapon abilities and magic spells that introduce things like shields that deflect magic or

swords that cast massive bursts of flame. The best *Elden Ring* fights, like the best *Souls* fights, ask that you study the way an enemy lunges at you and look for openings to punish them when they miss. In action, it's almost turn-based as you make your move and wait for the enemy to make theirs. *Elden Ring* is filled with encounters like this. Most of them are superb, but later in the game, some enemies and bosses come with so much health that it can be gruelling to get them down.

Once you understand the language of *Dark Souls*, it's clear where you should head next in its more contained world and where you shouldn't. A poison-soaked area might drain your healing resources on an initial run, but a forest nearby is full of herbs to stock up on. *Elden Ring*'s problems often have similar solutions, but because the map is so big and dense, it was hours before I understood where I was supposed

to use items like anti-poison herbs and armour built to withstand magic attacks that I found.

Ruts like that are worth climbing out of to see *Elden Ring*'s most tremendous moments. In its early hours, *Dark Souls* appears to be a typical fantasy setting with skeletons and dragons, but it eventually unfolds into an hourglass world where golden cities gaze down upon flooded ruins. When *Elden Ring* isn't recreating these locations, including that very same city down to the windows, or the poison swamp, or its own vacant version of the hub area, it's utterly magnetic. Below the Lands Between lies one of the most beautiful areas in FromSoftware's oeuvre, rivalling the sakura-hues of *Sekiro*'s final act.

Elden Ring is junk food for FromSoftware fans. It's more of what I already adore, but family sized. It has everything that makes these games so intoxicating, and that lodges their intricate fiction into my brain.

Below left: I sure hope this nice lady doesn't turn out to be as hard as nails boss fight!

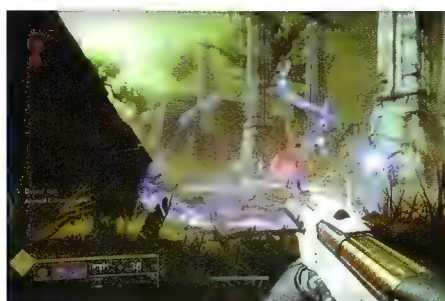
Below: Poison swamps are back.



Elden Ring is a world of tremendous secrets and battles – but I wish it was a little less familiar for a *Souls* fan.

Tyler Colp

★★★★★



\$59.95 | PC, XBS/X, PS4/5, Stadia | bungie.net

Destiny 2: The Witch Queen

Bungie delivers its best expansion to date.

If *The Witch Queen* does one thing right – and, in fact, it does many – it's that it brings a sense of consistency and stability to the game. It adds new features, yes, but they're all enhancements and progressions of systems and ideas introduced in *Beyond Light*. That rare sense of continuity allows *The Witch Queen* to instead stand out in a more meaningful way: by being *Destiny 2*'s best expansion. Finally, that future is here. The centrepiece is the campaign, which for the first time in *Destiny 2*'s history is itself a compelling reason to recommend this expansion. Previously, *Destiny 2* campaigns were little more than a path into the endgame – a handful of short missions, linked by rigidly templated repeatable activities and open world busywork. Here, though, it feels like the main attraction. Each of its eight lengthy missions is full of personality, progressing the story through a series of standout encounters and the occasional surprise. It starts as you assault a Cabal base on Mars – recently returned after being, er, borrowed by the Darkness – in order to fire yourself out of a cannon onto the titular Witch Queen's ship. From there, you

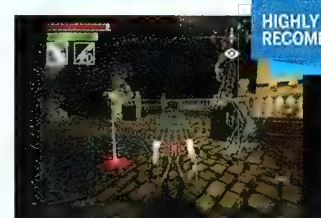
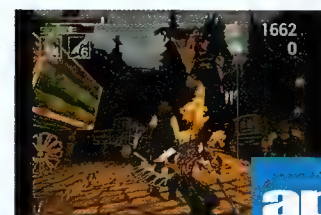
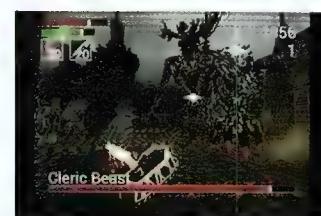
discover a portal into her Throne World, a sort of spooky alternate dimension made into a physical manifestation of its owner's personality. The gunplay is great too, of course. That's always been one of *Destiny 2*'s great strengths, and the campaign's encounter design capitalises on it well. I've heard that, on normal difficulty, *The Witch Queen*'s campaign is no pushover. But I played on Legendary – a new difficulty mode that hard caps your power level below the mission requirement, and adds new modifiers and challenge elements. It feels well-tuned for anyone with a decently filled Vault and a working knowledge of armour mods. Plenty of harder encounters forced me to engage with *Destiny 2*'s buildcrafting in a way that's rarely the case outside of the hardest endgame activities. It gives the complexity of the many ability systems, weapon perks, and mods a chance to shine.

There's still work to be done on the game at large, but *The Witch Queen* is a massive step in the right direction.

Phil Savage

★★★★★

Top: We're working with the Cabal now. Sometimes, at least.
Above left: Continuing everybody's obsession with tall monster women.
Above: Void 3.0 has ushered in the era of explosions.



apc

HIGHLY RECOMMENDED

Free | PC | b0tster.itch.io/bbpsx

BLOODBORNE PSX

Demakes a PlayStation 4 classic, with great results.

Here's PS4 favourite *Bloodborne* finally ported to PC – but as a PS1 game, complete with wobbly, warping textures, rigid controls, and loading screens galore. Of course, *Bloodborne PSX* is a fangame, but one that goes beyond a jokey tech demo or prototype to offer a pretty faithful recreation of *Bloodborne*'s opening hours, its cobbled streets, bosses, and all.

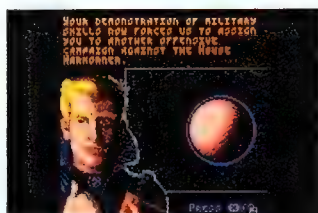
I've played *Bloodborne*. I've explored every inch of the city of Yharnam, and wow does this feel uncannily like it. The opening cutscenes have been recreated, but with low-poly character models and textures that look like a patchwork quilt. The enemies are as I remember them, in mostly the same places. It didn't take long for me to see past the downgrade, and let my memory guide me round these streets.

While obviously inheriting a lot from *Bloodborne*, taken on its own this is a tense action game with rewarding combat. A little fiddly to control, and too easy to get lost in, but with an atmosphere that oddly fits with that hazy 32-bit look.

A mix of the modern and the old-fashioned. Familiar yet uncanny, this captures much of what makes the original great.

Tom Sykes

★★★★☆



Free | PC | bit.ly/3vr6wX9

UNDUNE II

Remakes a classic in PICO-8 form.

You may have been hoping for a remake, but instead here's a demake of classic RTS *Dune II*. It's the game that birthed a genre, and for the last three years developer Paul Nicholas has been recreating it in micro game engine PICO-8.

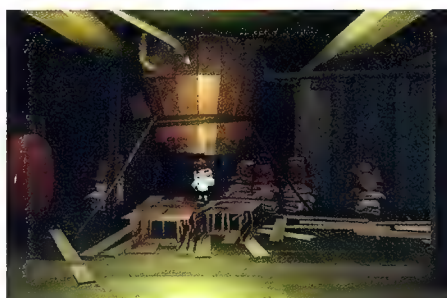
It's a bang-up job, I'm happy to report. All three factions, units and building types, and all the campaign missions are included here. It's a fully featured RTS (given the limitations of PICO-8), with a neatly streamlined interface and art that's clear and readable, despite the low resolution.

However, there are a few wrinkles that make it slightly awkward to play. There's no build queue and, worse, no way to drag-select units, meaning you have to select them individually when throwing everything you own at the enemy's base. It's frustrating, but not a deal-breaker, as this is not played out at blistering eSports speeds. It's a more stately real-time strategy, not to mention a less complex one by modern standards.

■ This is an impressive achievement that pushes PICO-8 to its limits, although it's not the ideal way to play *Dune II* today.

Tom Sykes

★★★★☆



\$28.95 | PC, BX1/S/X, PS4/5, Switch | farchangingtides.com

Far: Changing Tides

Traversing a drowned world in atmospheric puzzler.

Top: When the wind picks up, save fuel by pulling up the sail.

Above: You have a special suit that lets you breathe underwater.

Above right: This storm is a particularly exciting moment.

Civilisation has seemingly washed away on the tide. What remains is you and your boat, which you acquire shortly after the game begins. As you learn the boat's peculiar ways, *Far* keeps unveiling new surprises. By the end, I knew every nuance of this trusty vessel, like a beloved car.

When you liberate the boat, the only things you have to worry about are the wind and natural or man-made obstacles. The latter are generally cleared by hopping back off the boat and solving (mostly intuitive) mechanical puzzles, while the wind is something you manage from atop the deck. It's a simple enough system – dragging the sail around to follow the breeze – but the physics, sound design and animation all conspire to make it feel like you're really bobbing about on the water.

Multiple times, the game pulls back on the puzzling to allow you the simple joy of sailing, for surprisingly lengthy stretches of time. The soundtrack fades away, beautiful sights pass by in the background. It's just you and the ocean, as you keep one eye on the horizon and one hand gently tempering the wind.

This is *Changing Tides* at its best. Between moments of hectic boat management, this pure sailing is a satisfying reward.

Just when you're getting the hang of things on your boat, *Changing Tides* pulls the rug from under you and turns the vessel into a submarine, letting you plunge under islands and other massive things. Every so often, you need to dive into the deep for supplies, or hop onto some giant structure to yank switches, and do other puzzley things.

You're in the vessel for a long time – the journey kept going every time I thought it was over. And it does feel like a journey, more so than many games featuring massive open worlds. It all comes back to those moments, those empty stretches of sailing the open sea. It's just you, the boat, some lovely scenery and the shifting winds.

■ Satisfying sailing in a beautifully soggy apocalypse. I've never felt so connected to a vehicle in a game.

Tom Sykes

★★★★☆



\$28.95 | PC, XB1, Switch | nomorerobots.io/not-tonight-2

Not Tonight 2

Brings the *Papers, Please* formula to a shattered American landscape.

Not Tonight 2 features one of the bleakest opening sequences in the history of videogames. A crowd of black and brown 20-somethings are protesting outside a bar in Seattle when a van pulls up and a modern-day American Gestapo tosses one of them into the back of a van. Your friend is now incarcerated in a Miami 'gulag' on the other side of the continent, and it's up to you and your comrades to find a way to rescue them.

Like the first game in the series, it borrows nearly the full breadth of its mechanical functions from *Papers, Please*. You play as a bouncer, and the only way to generate enough gas money to make it to Miami on time is by working at every club that is left standing in a tattered America. In gameplay terms, that means you pull into some sort of deranged American locale, find a gig and check IDs for pennies before pulling into the next station for the next chapter of the linear story.

Your bureaucratic duty is supposed to feel like a drag, but *Not Tonight 2* comes up with just enough variations to keep it from being completely tedious. At first you'll simply be checking

to make sure your patrons are over 21 and don't have an expired licence, but before long you'll be scanning biometrics, seizing contraband, and kicking anti-maskers out of the queue.

Not Tonight 2 is not a particularly subtle videogame. On a jaunt to the southern border I found that Trump did in fact build his wall but, ironically, these days it's used more for keeping Americans in. A big-tech, neoliberal billionaire promised me deliverance in Raleigh; his name was Tom Swooney. At one point I found myself in a chicken slaughterhouse... where I used the same bouncer apparatus to decide which chickens were sent off to be butchered. There are moments of genuinely trenchant commentary, but the overall vibe here is so silly and relies on so many lowest common denominator clichés that it comes across like a formless synthesis of Twitter takes.

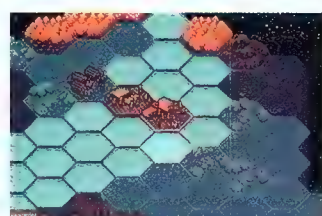
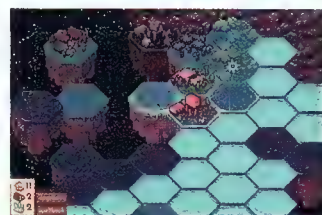
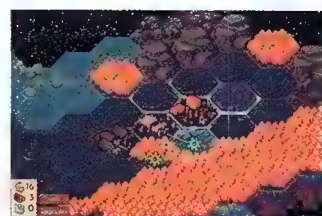
Does a decent job of adapting *Papers, Please* to a terminally hateful America, but the premise wears thin quickly.

Luke Winkie
★★★★☆

Top: The White House is a club now.

Above left: Chopping it up with the locals.

Above: In enemy territory.



Free | PC, Linux, browser
bit.ly/3BKiwua

KARAWAN

At world's end in this turn-based strategy.

The world is falling apart. Literally, it's falling off in clumps, which plummet into the abyss as you lead a caravan to safety. Can you make it to a mystical portal before you run out of food and, eventually, terra firma? It's a great idea, with some interesting systems holding up the hex-based world.

Initially moving just one unit, you'll soon steer it into villages to recruit farmers, woodcutters, and miners, which tag along on the hexes behind you. Farmers will harvest berries (for food), while the others will gather wood and precious gems from adjacent hexes. Wood is used to build bridges over otherwise impassable water, while gems are the currency for magical spells. You can swap certain tiles around, or flatten mountains to aid your progress.

You want to lead farmers to bushes, and woodcutters to forest tiles, while keeping up forward momentum on the front-most unit. Wasting a turn moving over an empty hex can mean the difference between life and death, if you haven't banked enough berries to reach the next harvestable bush.

Non-randomised levels cut short any replay value.

Tom Sykes
★★★★☆

The Goth family mansion in *The Sims 3* is a sprawling inspiration to build bigger.



GAME CHANGER

The Sims 3

Lauren Morton returns to the best building tools of the series.

RELEASE 2009 DEVELOPER Maxis PUBLISHER Electronic Arts LINK bit.ly/3vEIb4

For some, *The Sims* series is a wonderful sandbox simulation in which wacky fake people survive a gauntlet of unlikely house fires or where approximations of school crushes become spouses. For me, it's always been about the building. I've removed a few pool ladders in my day, but I've rarely given Live Mode the time of day since the original *The Sims*. It's always been about the architecture – learning to create floating houses tethered by staircases or designing mansions and realising I don't know what kinds of rooms mansions have. Piano rooms are a thing, right?

I happened to skip over *The Sims 3* – I was leaving for university and was really quite enamoured with MMOs when it launched – and now that I've come back to it I've realised that I missed out on the best building game in the entire series. *The Sims 3* is bliss for a builder like me.

New old tools

It's immediately more configurable than its follow up *The Sims 4*, starting with the neighbourhood editor. Unlike the tightly controlled neighbourhoods with pre-planned lots in the latest game, *Sims 3* allows you to place new lots in various sizes around the neighbourhood, in any spot that the terrain allows – and the terrain sure does allow. My very first lot placement was on more of a hill than I had planned for. Building a house perpendicular to a hill wasn't my intention, but I'm not one to cower from some impractical physics. But even the prebuilt lots in *The Sims 3* are frankly pretty brave in their choice of terrain.

After using the neighbourhood editing tools to plop a few extra trees and rocks just outside my new lot, I head into build mode to find out just how over my head I'll be in a 17-year-old game. Luckily,



the terrain tools for manipulating the dirt of the hill I plan to die on are largely familiar. It doesn't take me long to build a nice flat buildable space jutting out the side of my hill by using the raise terrain tool followed by the level terrain brush to create a buildable area and the soften terrain brush to make the edges of my house's eventual foundation less sharp. With all the dirt moved around to my liking, it's time to tackle a bigger project – a proper house.

Initially, I'm short on inspiration and slightly discouraged by the fewer style options available in *The Sims 3*.

It does have a lot of brick wall choices, and I get further discouraged as I slap them on the walls of my rudimentary box to find that the dated, lower resolution textures don't look so lovely on my big, modern monitor. Until I find my favourite tool in the entire game.



Above: My *Sims 3* home includes white-painted window trim and a rug I designed.



Right: A landline phone? Wow, this game really is old.



Knock on wood

Anyone who has spent time building in *The Sims 4* is certainly familiar with my greatest nemesis: wood swatches. *The Sims 4* has a frustrating fascination with wood furniture, all in different shades that never quite go together. Do you want your dining room table and chairs to match? Don't you dare mix sets. Want to experiment with some living room furniture from a few eras? Get ready for an

ugly wood grain rainbow. Don't even think about wood windows. I hope you like white, or those aren't going to match either. For all its countless options, *The Sims 4* really requires that you stick to certain combinations of objects that are meant to go together. Even after adding hundreds of new colour swatches to all sorts of decor in a 2021 update, *The Sims 4* annoyingly refuses to get matchy.

In complete contrast is *The Sims 3*'s greatest feature: the all

powerful, much beloved, and dearly missed Create-A-Style. This handy tool includes all of *The Sims 3*'s material swatches for woods and carpet and cloth and metal, along with a colour picker to change those materials to any hue you please. You can apply any pattern and any colour to just about any object you like – whether it's windows or columns or couches or lamps. Unlike *The Sims 4*'s highly curated collection of options, *The Sims 3* just puts the entire craft box in my hands and says 'good luck'. And oh how lucky I feel! Time to sort out that matching window conundrum once and for all. I deserve to know some sort of peace.

I slap down five different windows in totally different styles and, of course, they do not have matching natural wood colour options by default. One option is slightly too orange-y, another too dark. I can't possibly get them all to play nicely together... until I open up the Create-A-Style tool, and use its magic to drag and drop the material and colour from the menu.

SWATCH WATCH

My new favourite patterns



SUBWAY TILE

This look is going to be perfect for a modern kitchen backsplash. It'll be a statement about urban living.



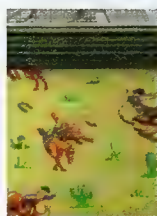
TUFTED UPHOLSTERY

Upholstered walls? Yes, I think I will find a way to make this work. Or just put it on a sofa.



GEOMETRIC PATTERNS

My current favourite geometric pattern, which looks great with subtle, slightly different colours.



WILD WEST

This delightfully tacky print features cowboys riding bulls. I'm eager to create design crimes with this in some fashion.



Right: The best part of this exterior is the matching windows and decks.

Above: *The Sims 3*'s default builds go absolutely wild with terrain.

Far left: My *Sims 4* tiny house inspiration.

Let me present to you, my fellow *Sims 4* builders, with several windows in different styles, that all have matching natural wood colour.

Behold their beauty and my top-notch design skills.

Frame perfect

With the window situation handled, I really start colouring outside the lines, digging deep into *The Sims 3*'s weirdest patterns and revelling in anything unlikely I can throw them on. After

RUGGED

Make any rug you can imagine! Such power...



1 I've picked a nice, normal striped pattern for the outer rim of this rug – starting simple is key.

2 This pattern has three different colour channels for the outer, second, and inner stripes.

3 The interior pattern is a geometric one, with two colour channels that I matched to the exterior.

discovering the majesty of creating cow print wallpaper and metallic upholstered armchairs, I decide it's time to pit *The Sims 3* against *The Sims 4* directly.

I pulled up a tiny house I recently built in *The Sims 4* and got to work copying it in *The Sims 3*. It takes me several minutes to figure out that creating a foundation and deck for the lot works differently than in the newest *Sims*, but after plotting both out, building is largely quick and familiar. Aside from the roofs. I don't want to talk about the roofs. I'll never master them in any *Sims* game.

The power of *The Sims 3*'s Create-A-Style is both in its openness and its precision. Many items, like a sofa for instance, have several slots corresponding to their parts – one for the arms and one for the cushions in this case. I can use any pattern I like in those slots and also choose a colour for them. Patterns often have multiple colour channels, even. It's a rabbit hole of design choice. To keep things tidy though, I can favourite a material I've created, or grab the hex code colour from a piece to



pick one that matches it. Not all materials wear the same colour exactly the same, so there is a little fiddling on my part to make the wood slat boards on my walls match the crown moulding above them, but the power to fuss with the colour picker until I'm happy is fully in my hands.

In all my experimenting, the wall treatments and rugs are the biggest beneficiaries of the Create-A-Style tool. Although *The Sims 3* has plenty of its own wallpaper and wall paint options, with and without trim or crown moulding or beadboard, there's so much power in changing a floral wall print to exactly the shade of blue I was looking for. As in real life, those wall colours set the personality for an entire space. Rugs, which I've never gotten on with in *The Sims*, are now one of my favourite little design puzzles.

It strikes me, as I'm picking the exact light brown shade of vaguely oak for my kitchen cabinets, that this is the point at which I should probably be stricken with choice paralysis. *The Sims 3*, through the majesty of the Create-A-Style tool, gives me an excess of options that would

normally have me shutting down and overwhelmed, but I am absolutely enamoured with it.

In *The Sims 4*, I lose so much time agonising over the swatches I'm given, trying to creatively mix living room furniture sets and knowing that the bar for success is just finding the combination that clashes least. In *The Sims 3*, I'm free to choose a coffee table and sofa whose silhouettes I like and then give them matching wood tones that make them look as if they definitely came from the same home store collection.

By the end of all of this, I've created a custom wallpaper with a subtle geometric pattern that I'm quite proud of, designed a dining room set in matching wood colours, and put my personal touch on the marble kitchen counters too. I created matching windows throughout the house which have natural wood on the outside and are white on the inside because it reminds me of the way that people flip houses by painting wood trim white where I'm from. I definitely went off spec at some point, adhering to the shape of my *Sims 4* build inspiration but not necessarily it's

colours. Even so, the experiment is more of a success than I anticipated.

Strong foundations

The Sims 3 is certainly older. Its textures are lower resolution and it has a more realist visual design that's not as charming as the stylised *Sims 4* look. But this house is so much more mine than the one I built in *The Sims 4*. I've designed nearly every piece of furniture in it exactly the way I like, not even bothered by the relative lack of silhouette choices compared to its newer sibling's catalogue. For even further choice, *The Sims 3* allows you to import new swatches and materials created by other players. It's impressively permissive, and not to a fault.

I don't think *The Sims 3* will generate the lovely screenshots I'll want to show off in build challenges with other Simmers, but I'm positive that I'll return here any time I have a specific look in mind that I know *The Sims 4* simply doesn't have the swatch options to support. Oh, and *The Sims 3* has garage bay doors. Truly, what more could I want? ■



RETRO

RETRO



BLAST FROM THE PAST COMPUTERS IN SPACE

Spacecraft used to explore the solar system may be fast, but the computers on board are often old and slow, as David Crookes discovers.

It is often said that our mobile phones are far more powerful than the computers used to put Neil Armstrong and Buzz Aldrin on the moon in 1969. In fairness, that's to be expected. Half a century is a long time in technology.

More surprising is that the computer on board the US space agency's New Horizons probe, which reached Pluto in 2015, was also less smart than a smartphone. So too is the computer on board NASA's Orion spacecraft that will, one day, send humans to Mars.

It may appear rather strange. NASA has been at the forefront of technology for decades, giving us cordless vacuum cleaners, solar cells, wireless headsets and air purifiers, among others. Yet it also tends to lean towards the tried and tested.

"For us, it's all about reliability," said Alan Stern, principal investigator of the New Horizons mission. "After all, you can't fit technology on the way to Pluto, so reliability and long parts and operations experience far trumps the need to use the fastest, newest computers in the spacecraft we send off to the planets."

In the case of New Horizons, which launched in 2006, astronomers made use of a 32-bit Mongoose-V RISC processor with a

clock speed of just 12MHz. Created by Synova, it was based on the MIPS R3000 CPU introduced in 1988, a CPU that was actually used in the original PlayStation a few years later. To ensure the chip could withstand its long journey into space (the probe is now more than 50 times further from the Sun than Earth is), the processor was radiation-hardened.

Even though it perceptibly lacked power, the computer has been responsible for the bulk of the spacecraft's processing capability, guided by intricate flight software. It collects and processes instrument data, distributes operating commands to each of the probe's subsystems and runs algorithms that check for problems, correcting them if necessary. It has been a huge success.

"When we plan a mission, there's always an involved process of parts selection," Stern told APC. "We set technology requirements and then find a flight computer that meets our needs, same for all missions." And yet at one time, NASA did rely purely on cutting-edge tech for its spacecraft.

More chips, please

Although the New Horizons computer is far more powerful than the one used on board Apollo 11

Above: Orion will take a crew to Mars using a processor slower than a smartphone's.
Below: NASA's mission control room in 1969, monitoring the first moon landing.



that landed the first humans on the moon, the Apollo Guidance Computer (AGC) was advanced for the time. But computing was still in its infancy, so it had to be.

Developed by the Massachusetts Institute of Technology (MIT), the AGC contained thousands of silicon chips yet it only had 74KB of ROM, 4KB of RAM and it operated at 0.042MHz. The use of such chips was relatively new. The first working integrated circuit had only been demonstrated in July 1958 by American electrical engineer Jack Kilby while he was working for Texas Instruments, and a patent had been filed the following year.

NASA's Apollo Program seized the opportunity to make use of the technology, becoming the largest consumer of semiconductor chips between 1962 and 1967, snapping up more than 60 percent of those made in the United States. It took 300 people seven years at a cost of \$63 million to create the mission software, including the on-board program Luminary, yet the move was pivotal.

NASA's fierce appetite for integrated circuits led to the rapid rise of Silicon Valley and it helped the price of the chips to plummet so much that they were selling for \$20 by the time Neil Armstrong was making his one small step.

The important thing is that the technology – while primitive by today's standards and no better than a pocket calculator – was more than sufficient. It not only got humans to the Moon, it ensured they came back.

Astronomers would use a calculator-style keyboard to input commands using numerical codes (the digits representing verbs and nouns), and these would tell the spacecraft what to do. It was a method that worked, and the performance of the computer was so great that in just a few years consumers could start to enjoy similar technology in the likes of the Apple II and Commodore PET.

If it ain't broke

Apollo's mission control computers on the ground were a tad more advanced, however. The engineers and flight technicians used five IBM System/360 Model 75 mainframes released in 1965, along with other systems, and they were among the most powerful computing systems in the world at the time.

One of these machines was used to calculate the lift-off data used in Apollo 11 for the flight back to



The Apollo Guidance Computer allowed commands to be entered numerically.

Earth, according to IBM. "We use up-to-date computers in our Mission Control, too, because they can be repaired or replaced easily," said Stern.

But that's not always the case. James Mason, who today works as a research scientist and engineer at the Applied Physics Laboratory at John Hopkins University in Baltimore, Maryland, US, recalls a visit to the US government's White Sands Test Facility in New Mexico. The laboratory contains computers that support the sensors on board NASA's Solar Dynamics Observatory, which launched in 2010.

As reported in the journal *Nature*, data was streaming to a desktop computer dating back to the 1980s. "It was a TD-plus and I've spent a lot of time trying to find information about it," Mason told us. "But I've seen this kind of thing at NASA before, as well as at the US National Institute of Standards and Technology, because, well basically, if it ain't broke, don't fix it."

"If we had an abundance of time and money then we'd keep those systems up to date but we've just got other things to do that are more directly related to the end goal of why we are at such facilities in the place – to get a new instrument calibrated or to launch a telescope into space to gather the data."

"Even without keeping all of the resources, like the computers, constantly up to date, and the whole team trained on what's changed, we

have months of work leading up to and after each of these events. So that's why these systems get used."

It suggests an underlying ethos that proven technology should be retained until it proves unreliable. Once a computer looks to be on its last legs, or if there is a compelling reason to upgrade to do a job better and equally reliably, then it will be replaced – assuming it isn't millions of miles away.

As further proof, Commodore Amigas were number crunching and analysing images in NASA's research offices from the 1980s until 2004, long after the range was discontinued in 1996. The computers proved to be a good way of processing launch vehicle telemetry until something better came along.

But is the old 1980s computer at White Sands still in use? Alas, no. It ended up being ditched in 2015 because a connector and ribbon cable – "one of those old, wide rainbow ones," said Mason – were starting to fail. Yet it would have made life easier had it continued to work well.

"The connector in particular was not staying connected and we'd get intermittent dropouts," he added. "But I have to say that working with the replacement has been a mixed bag. Yes, it's got a really cool display that looks a lot like the Hollywood depiction of NASA, but it's also vastly more complex and it took us multiple weeks just to get it configured correctly at our most

recent launch in September last year.

"The TD-plus was super simple and it never changed year to year so it would take about five minutes to get it set up for each launch. It didn't look like much, but that time we didn't spend fiddling with something new was time we could spend on more pressing parts of the rocket schedule."

Space invaders

The replacement would have been introduced after much research into its suitability, however, although personal preference and cost is also taken into account. There's an insightful video on YouTube (tinyurl.com/APC506AMIGA) dating back to 1998, for example, in which Gary Jones, then principal systems engineer for NASA, shows Amiga computers at Hangar AE. The machines were supporting the launch of the Space Shuttle Endeavour to the Russian Mir space station, but Jones said the first choice had been a selection of Apple Macs until NASA realised they were too much of a closed system.

Jones also revealed that the space agency had wanted to use PCs running Windows 95 and NT instead, but the engineers kept insisting they weren't fast enough. DEC Alphas, based on 64-bit RISC architecture, were proposed but seemed too expensive.

Oddly, it was felt that the Amiga didn't cost enough, but they made it the building nevertheless. And to show how widely they were one Commodore computer Amiga 2500 released in 1987 put up for sale on eBay 30 years later, having been used by Telemetry Lab. It sold for \$6,800.

These are machines on the computers sent as integral parts of are generally tested thoroughly. "There's an of NASA called the logy Mission it, among es a lot of satellites e how new l perform and future science said. "But even in of the satellite nponents so that t data back ology in

more than
spacecraft to

The New Horizons space probe used the same CPU as the original PlayStation.



contain processors that are getting on for 20 years old. Its priority is for the chips to survive a journey to Mars through the Van Allen belts above Earth, where it will be bombarded with radiation. The Honeywell flight computer runs on two IBM PowerPC 750X single-core processors that have been around since 2002. Originally used in Boeing 787 jets, the processors are considered to be more than up to the job.

"In general, it takes about three

years to build flight hardware and get it ready for flight," Matt Lemke, NASA Orion avionics, power and software manager told APC. "We are limited in what processors we can select due to the need for extreme reliability as well as the radiation environment that ground systems don't need to be concerned with.

"Once we have gone through the expense of selecting a processor and building it into the flight hardware, we don't change unless



The Asus P6100 lasted 600 days on board the Russian Space Station Mir.



there is a compelling reason. The selected processor for Orion has all the computing power we need and it has been working great. So far it has been used in our pad abort flight test, the Exploration Flight Test -1 mission, the upcoming Artemis I flight, and we anticipate using [it] all the way through Artemis XII."

Even so, precautions have been taken. "We build them into a ruggedised custom design," said Lemke. For example, the computer has been placed within a larger case and the hardware and circuit boards are thicker. But just in case the worst happens, three computers are going to be on board – the third one acting as a backup should the other two go kaput or at least end up having to be reset (if this happens, they'd be down for 20 seconds, and that can be a long time when travelling at great speed).

A hard drive

Astronauts also use personal computers in space and these, too, are carefully selected. The first laptop to fly on the Space Shuttle was the GRiD Compass, which, after beginning development in 1979, was released three years later. Starting with model 1101, it used a clamshell case made of magnesium alloy and it weighed 4.5kg, which was less than half that of its main competitor, the Osborne 1.

Packing a 16-bit Intel 8086 chip, 340KB of magnetic bubble memory and a 1,200bits/sec modem, the computer also had an 8.5in, 320 x

Top: Five IBM System/360 Model 75s calculated lift-off data for the first lunar trip.
Above: Asus' ZenBook 14X OLED Space Edition is built to withstand extremes.

240 plasma screen. It included a magnetic storage system, too, and the lack of moving parts made it ideal for the rigours of space, which is why NASA sent it on board the Space Shuttle Columbia on 28 November 1983.

Codenamed SPOC (or Shuttle Portable On-Board Computer), astronauts used the GRiD Compass for on-board navigation, tracking fuel and checking other data on board the shuttle, as well as for planning their time, including photo shoots. NASA's faith in the aged computer was justified in January 1986 when it survived the terrible Challenger shuttle disaster, which claimed the lives of all seven crew members aboard. Once recovered, the GRiD Compass continued to work.

There have been many other computers on board spacecraft since, including a few Raspberry Pi devices. In 1997, Asus saw its P6300 laptop launched into space, and two P6100 laptops lasted the full 600 days aboard the Mir space station the following year. Asus

marked the 25th anniversary of this moment in its history by launching the ZenBook 14X OLED Space Edition earlier this year. It says the new machine could also withstand going into space having been put through its paces by NASA, and that standards have improved greatly over the years.

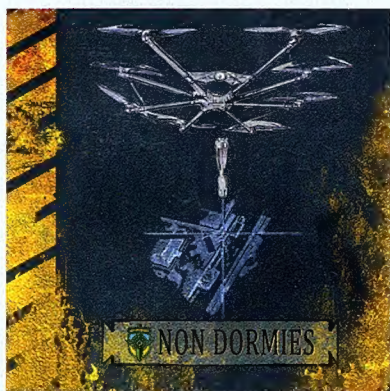
"The testing procedure is now rigorous and includes being tested at high altitudes, extreme temperatures (high and low), extreme shock pulses and being exposed to sand, dust, fungus and solar radiation," said Ciprian Donciu, an Asus country manager, who adds that the device has to continue working throughout.

"But this was not the case 25 years ago. The requirements for space testing were completely different, yet our laptops lasted. After the Mir station experienced electrical and some technical issues, the laptop itself was one of the few items on board that was able to be successfully used by the Russian astronauts consistently. It was so reliable that the cosmonaut personally thanked Asus."

It's likely that space agencies will continue to mix old with new for some time to come, selecting tech entirely on its merit rather than its age. Although NASA could afford the most cutting-edge computer components, there is simply too much at stake. "We have to work with a known quantity," James Mason said. "It simply poses a lower risk." ■

CHIP CHAT

JOEL BURGESS REPORTS ON THE UNUSUAL SIDE OF TECH NEWS



UKRAINIAN DRONE VOLUNTEERS STALL GIANT RUSSIAN TANK CONVOY

IT hobbyists stifle primary Russian military assault with clever tech tactics.

According to *The Guardian*, a team of 30 Ukrainian special forces that began eight years ago as a group of volunteer tech specialists and drone hobbyists, played a critical role in stifling a 40 kilometre long convoy of Russian tank battalions as it rolled towards Kiev. The Aerorozvidka air reconnaissance unit used quad bikes to access the roads the tank regiment was advancing on at night by driving through the forests either side of it. Using night vision goggles, sniper rifles, and drones carrying small bombs, the Ukrainian tech team was able to destroy vehicles at the head of the convoy and effectively block the Russian advance.

FACEBOOK INVESTS HEAVILY IN DISHING DIRT ON COMPETITION

Meta paid a lobbyist firm to call TikTok kettle black.

Targeted Victory, a large Republican leaning lobbyist firm in the US, was hired by Meta to run a targeted PR campaign smearing Facebook competitor TikTok to divert focus from the social media giant's own shortcomings, according to a report by *The Washington Post*. While this isn't going to be the first time a large company has smeared its competitor, it is the first major example of Facebook's Project Amplify campaign, designed to manipulate the media into spinning a more positive light on the company, which was signed off on in January 2021 by Mark Zuckerberg.



Dyson Zone air purifying headphones

Now the rich can take their purified personal air bubble into the sick urban landscape.

Dyson has always managed to bridge the gap between mundane household appliances and exciting new must-have tech by innovating in creative and engaging ways to meet the demands of today, but has it gone too far this time? The Dyson Zone are air-purifying headphones that leverage some of the company's leading air filtration technologies into a portable headset that might be appealing to some in a pandemic-stricken and highly polluted urban environment. We're not sure what to expect from the headphones – Dyson hasn't really proven its chops at designing good quality audio drivers recently, but the company at least understood that it probably wasn't going to get over the line on mass market portable air filtration without some other drawcard.

US\$500K 'NOT ENOUGH' FOR RARE NUDE PEPE NFT

Furry Pepe NFT owner launches lawsuit over the digital image's lack of value.

Matt Furie, the digital artist that has been battling for years to liberate his Pepe the Frog character from being used as symbolism by the alt-right, created a fan fiction-type image of the frog's bare butt bathing in a rainforest pond and partnered with autonomous blockchain organisation PegzDAO to mint a copy of it and sell it at auction in October of 2021. The auction was won by Halston Thayer, according to Motherboard, for a sum of 150ETH, which is over \$650K+ at the time of writing. Instead of being a totally unique item this particular NFT was one of 100, a detail that Thayer didn't do enough due diligence on before purchasing. When the remaining copies came on the market Thayer's NFT value plummeted to just US\$30K. Thayer is now suing Furie for fraud to the tune of \$507,084. ■





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"For young people, using technology isn't solitary or antisocial, it's a tool for self-expression, a way to explore new interests, communities and identities."

Mimi Ito, Cultural Anthropologist



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